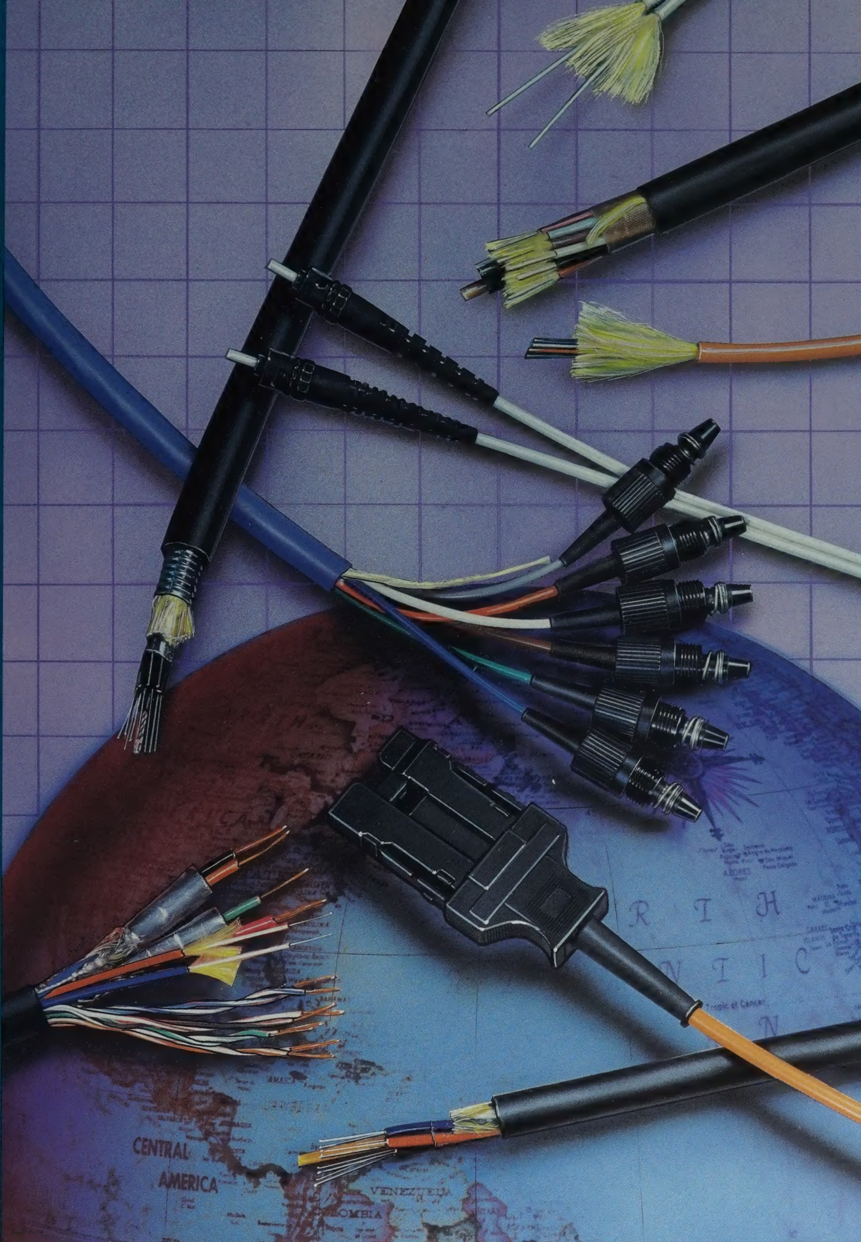
Belden
Wire and Cable



Belden

Fiber Optic Catalog

Since 1902, Belden Wire and Cable products, processes and development strategies have been driven by the needs and desires of our valued customers. By listening and responding with high-quality, cost-effective solutions, Belden has maintained a tradition of quality, consistency, and innovation.

From the leading edge of our fiber optic technology to the roots of our long-standing total quality commitment, our customer-oriented focus has never changed.

The addition of a state-of-the-art Engineering Center to Belden world headquarters represents a major commitment to leading the industry in research and development.

Today's Changing Environment

Today's computer operating environment requires integration of dissimilar mainframes and networks (Ethernet,▲ IBM Token Ring,▼ Arcnet,[9] etc.) and must accommodate transmissions of all types—voice, data and video. Belden® fiber optic cabling products have been designed and manufactured to satisfy such operating environment challenges. One of the more popular solutions consists of fiber as a backbone or trunk cable with twisted pair to the desk. Other system environments and plans call for all-fiber networks. Whatever the system challenge, Belden is ready to deliver its cable (fiber or metallic), manufactured to tightly controlled specifications, for the unique solution your situation requires.

Because fiber optics is the recognized technology for cost-effective investment in the future of communications, today's large scale fiber installations are laying the foundation for tomorrow's communications. Alternative Local Carriers (ALCs) are installing Metropolitan Area Networks (MANs) in most major metropolitan areas. The Fiber Distributed Data Interface (FDDI) is bringing new light-speed communication to corporate campuses and universities, helping them to operate more effectively and reliably while allowing for future system growth. Fiber To The Curb (FTTC) economically delivers fiber near the home by sharing the large cost of electronics.

Today's changing environments demand network cabling solutions which are adaptable and "future-proof." Belden fiber optic cables not only offer you a hedge against your future system needs, but the inherent advantages of fiber optic technology as well: immunity from electromagnetic interference, high bandwidth performance, space efficiency and security. All fibers feature a dual-window construction, which allows for future system upgrade. It's no wonder Belden fiber optics have become the natural choice for closed circuit television, government network security, factory automation and major commercial networks. In applications such as video conferencing, medical imaging, and CAD/CAM, Belden fiber optics feature unparalleled performance.

In tomorrow's operating environment, the development and implementation of standards such as SONET and FDDI-II will increase the installation of fiber networks and create more efficient use of currently imbedded fiber lines. Belden is committed to the development and support of highly effective fiber solutions. From micro to macro, standard or complex, Belden offers a fiber optic cable designed for your current and future environments.

▲ Xerox trademark. [9] Data point Corp. trademark ▼ IBM Corp. trademark.

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Belden is committed to FDDI. The Fiber Distributed Data Interface will evolve and changes are inevitable. Belden is involved with the ANSI X3T9.5 committee (and nearly all standards groups) and will actively lead further development of fiber optic standards. As cable specifications within FDDI change, Belden pledges to its customers to support those changes with the best product for the best value.

How To Use This Catalog

BELDEN

If you need to...	*Review this catalog section...*	*On pages...*
1. Define Your System or Network Requirements	**Application Illustration** This network application illustration identifies many uses for Belden® fiber optic cable by color code. Select the cable family for your particular system need and follow the color coding throughout this catalog for additional information. BitLite® LANLite™ Breakout SuperLite™ Interbuilding Trunk—Multifiber Per Tube Interbuilding Trunk—Bundled Special Application Cables	3–4
2. Select a Belden Cable Family	**Cable Selection Guide** Follow the color codes and refer to this reference guide for an overview of network cable family features.	6–7
3. Identify Belden Products for Special Applications	**Special Applications Products** This section presents an overview of general purpose indoor cables, DECconnect* cables, assemblies and other special applications products.	8
4. Select Connectors	**Connector Guide** This section illustrates and describes popular fiber optic connectors for use with Belden cable assemblies.	9
5. Identify Part Numbers and Specifications	**Belden Product Catalog** Easily recognized symbols organize the catalog section: **Fiber Optic Cables** (also organized by color coded cable families)	10–28
	Connectorized Cable Assemblies	29
	Breakout Kits	30
6. Locate Additional Services or Information	**Belden Customer Services**	37–39
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7. Look Up a Product by Part Number	**Part Number Index**	69
8. Locate Cables by Construction	**Cable Finder Chart**	31–36
9. Place an Order...		
For Catalog Items	Call your local Belden sales office at **1-800-BELDEN-1** for the Authorized Belden Distributor or Systems Integrator nearest you.	38
For Custom Design Service	Call Belden Product Engineering at **1-317-983-5200.**	37

* Digital Equipment Corporation trademark.

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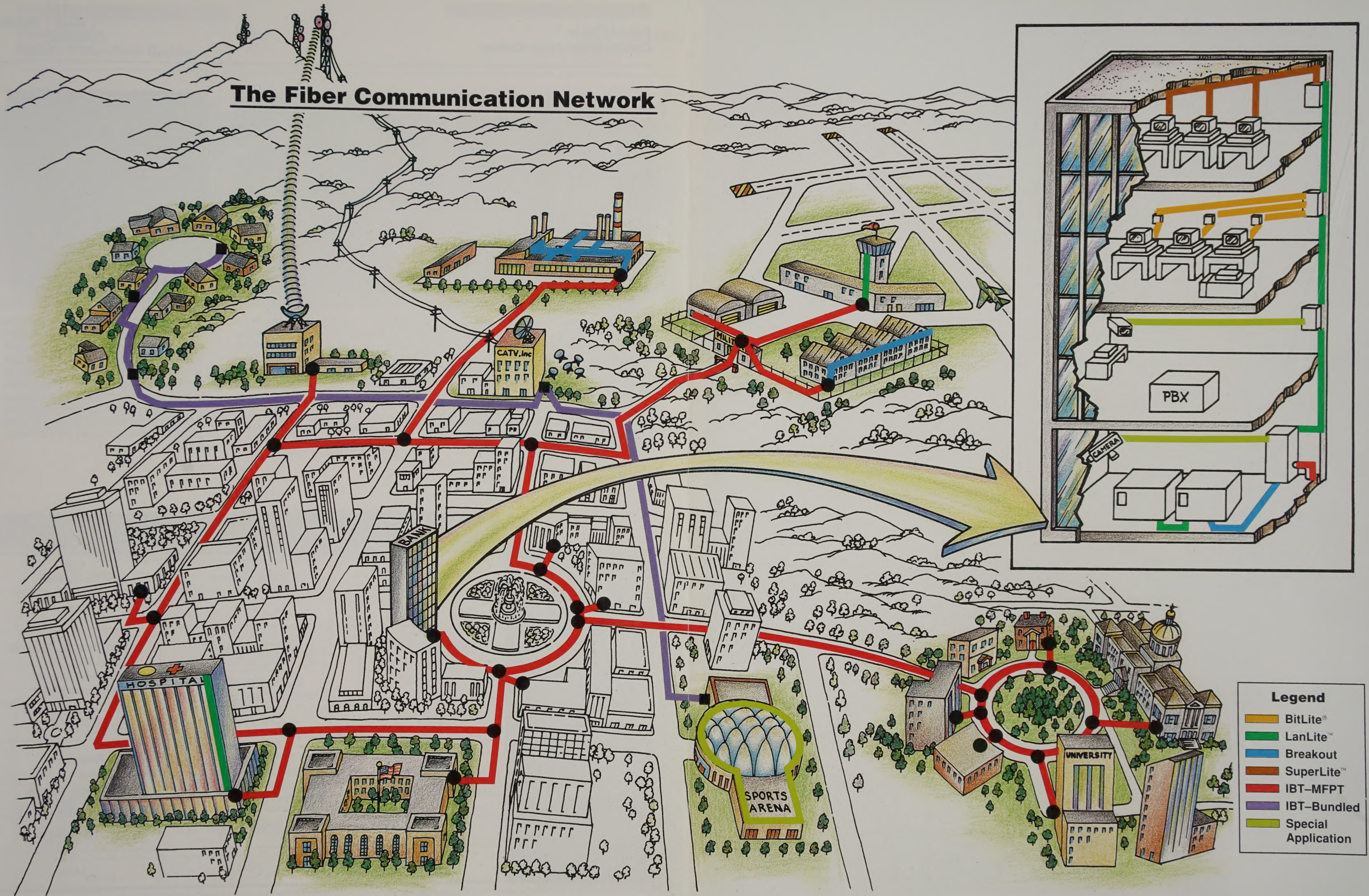
The Fiber Communication Network



BELDEN

COOPER INDUSTRIES

■ **SuperLite™ Cables.** Belden® SuperLite cables with a hybrid combination of copper pairs and fiber provide the capability of transmitting telephone voice signals and high speed data within the same cable. This type of hybrid cable design provides the advantage of utilizing current copper technology with the opportunity to upgrade to fiber for future applications.

■ **Interbuilding Trunk Cables (Multifiber Per Tube).** Belden's interbuilding trunk cables are ideally suited for Wide Area Networks, multi-building interconnection, and broadcast and video applications such as CATV supertrunk and satellite uplink/downlinks. The multifiber per tube (MFPT) design consists of 1 to 72 fibers contained in loose, gel-filled buffer tubes. This family of cables is available in armored, dielectric, and double jacketed versions.

■ **Interbuilding Trunk Cables (Bundled).** The bundled fiber version of Belden's interbuilding trunk cables consists of 4 to 72 single mode fibers, bundled in groups of 6 or 12, and contained within one, gel-filled polyethylene core tube. Cables containing 36 fibers or less utilize 6 fiber bundles. Cables with fiber counts of 48, 60 and 72 are comprised of groups of 12 fibers bundled loosely together with a spirally applied binder. These cables are available in both armored and unarmored dielectric versions.

	SuperLite™	Interbuilding Trunk Multifiber Per Tube	Interbuilding Trunk Bundled
Tight/Loose Buffer & Indoor/Outdoor	Tight Indoor	Loose Outdoor	Loose Outdoor
Number of Fibers	2	1–72	4–72
Fiber Sizes	62.5 with IBM Type I, II, III	Single Mode, 50, 62.5	Single Mode
Strength Member	Kevlar® (with fiber)	Kevlar only or FGE with Kevlar	FGE or Steel
Jackets	PVC, FCP	PE, PVC	PE
Armored/Dielectric	All dielectric fibers plus copper conductors	All dielectric (with single or double jacket) or Armored	All dielectric or Armored
Termination	Connector may be directly attached	Breakout kit required or spliced	Breakout kit required or spliced
NEC • U.L. • CSA	CMR-OF, CMP-OF	N/A	N/A
Catalog Pages	17–18	19–22	23–24

■ **BitLite® Cables.** These small, flexible cables are commonly used as jumper cordage for drop cable to the device or to interconnect equipment within a wiring closet. This cable utilizes the tight buffer construction for direct connector attachment. The tight buffer style provides a smaller cable diameter, greater flexibility, and much greater crush and impact resistance than loose-tube cables of equivalent fiber count.

■ **LANLite™ Trunk Cables.** LANLite Local Area Network trunk cables are designed for indoor applications that provide high bit-rate communication between mainframes and building distribution systems. LANLite can also be used for outdoor applications in a protected environment.

■ **Breakout Cables.** Breakout cables can also be used in Local Area Network applications. These cables provide the additional advantage of individually strengthened fibers ready for direct connector attachment. Breakout cables can be used in indoor applications as well as in protected outdoor environments. Each individually jacketed single fiber unit accepts all of the popular connector types on the market today.

	BitLite®	LANLite™	Breakout
Tight/Loose Buffer & Indoor/Outdoor	Tight Indoor	Tight Indoor/Outdoor	Tight Indoor/Outdoor
Number of Fibers	1 & 2	2–12	2–24
Fiber Sizes	Single Mode, 50, 62.5, 100	Single Mode, 50, 62.5	Single Mode, 50, 62.5, 100
Strength Member	Kevlar•	Kevlar	Kevlar only or FGE with Kevlar
Jackets	PVC, FA	PVC, FA, FCP	PVC, FCP
Armored/Dielectric	All dielectric	All dielectric	All dielectric
Termination	Connector may be directly attached	Terminated in protected enclosure or breakout kit required	Connector may be directly attached
NEC•• · U.L. · CSA	OFNR, OFNP	OFNR, OFNP	OFNR, OFNP
Catalog Pages	10–11	12–13	14–16

• DuPont trademark.
•• Tradename of National Fire Protection Association, Quincy, MA.
FGE = Fiberglass Epoxy Rod

PE = Polyethylene
PVC = Polyvinylchloride
FA = Flamarrest®
FCP = Fluorocopolymer

Fiber Optic Cable Selection Guide

COOPER INDUSTRIES BELDEN

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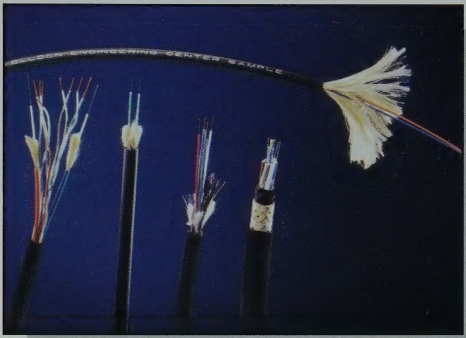
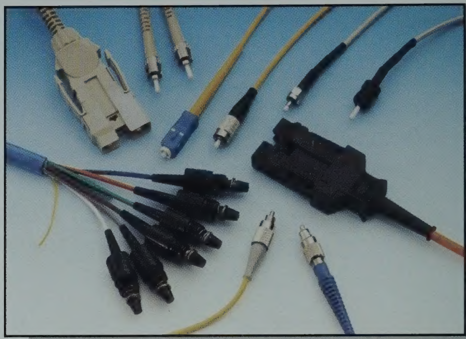
SuperLite™	Interbuilding Trunk Multifiber Per Tube	Interbuilding Trunk Bundled	
Tight Indoor	Loose Outdoor	Loose Outdoor	**Tight/Loose Buffer & Indoor/Outdoor**
2	1–72	4–72	**Number of Fibers**
62.5 with IBM Type I, II, III	Single Mode, 50, 62.5	Single Mode	**Fiber Sizes**
Kevlar® (with fiber)	Kevlar only or FGE with Kevlar	FGE or Steel	**Strength Member**
PVC, FCP	PE, PVC	PE	**Jackets**
All dielectric fibers plus copper conductors	All dielectric (with single or double jacket) or Armored	All dielectric or Armored	**Armored/Dielectric**
Connector may be directly attached	Breakout kit required or spliced	Breakout kit required or spliced	**Termination**
CMR-OF, CMP-OF	N/A	N/A	**NEC • U.L. • CSA**
17–18	19–22	23–24	**Catalog Pages**

Fiber Optic
Special Application Products





■ Special Application Cables

In addition to our broad standard product offering, Belden manufactures cables for specialized applications. With the resources of the Belden Engineering Center, we can offer constructions the competition won't touch.

We also offer as standard, cables for the DEC Fiber Optic Network (DFON). DECconnect✧ jumper cordage, light-duty and heavy-duty cables are available from stock in the length of your choice.

For information on the DECconnect cable line, see catalog pages 27–28.

We also are one of the industry leaders in halogen-free cable constructions. Call Belden Product Engineering at **1-317-983-5200** for further details.

■ Connectors and Cable Assemblies

Belden® fiber optic cables can be cut to any length desired and terminated at one or both ends with any popular connector of your choice, including:

- Siemens FDDI-MIC Connector (AMP, AT&T and Molex also available)
- ST-Compatible
- SMA
- Biconic
- FC
- D4
- SC

See catalog page 29 for assembly ordering information.

■ Flamarrest®—Belden's New Jacketing Innovation for Plenum Fiber Optic Cables

Belden proudly introduces a jacketing innovation which will literally change your understanding of plenum cable. Flamarrest not only incorporates a host of significant technical advantages, it comes to you less expensively than cables with traditional fluorocopolymer jackets. With Flamarrest as an option, you will find there is no comparable plenum cable.

- U.L./N.E.C. Rated OFNP (Plenum)
- 5 times more flexible than fluorocopolymer
- Lays flat–no spiraling effect
- Lighter weight per unit
- Easier to handle, simple to connectorize
- No knuckling or cracking
- Printable jackets, custom color options
- Extremely cost effective for long cable runs

You can find Flamarrest options available on Belden BitLite and LANLite cables on pages 10–13.

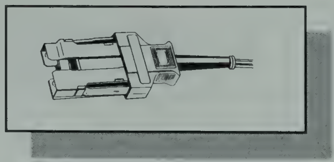
✧ Digital Equipment Corp. trademark.
® DuPont trademark.
† AT&T trademark.

Fiber Optic Connector Guide

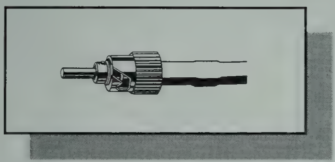
BELDEN

This fiber optic connector guide presents brief descriptions of popular connectors available for use on any Belden® fiber optic cable assembly. **For assembly ordering information see catalog page 29.**

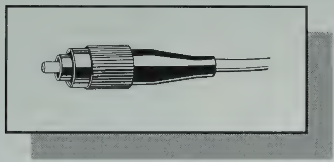
For further assistance and connector selection for a Belden cable assembly, contact Belden Product Engineering at **1-317-983-5200.**



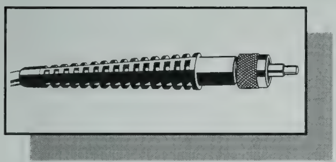
■ **FDDI.** Duplex fiber optic connector system with ceramic ferrule, fully compatible with ANSI FDDI PMD document. For data communcations applications, including FDDI backbone, frontend or backend networks and IEEE 802.4 token bus. Dry connection, with positive latching mechanism. Low insertion loss.



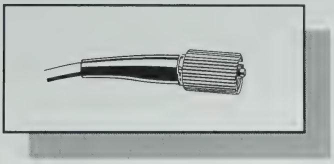
■ **ST Compatible.** Small size connector with keyed bayonet coupling for simple ramp latching or disconnect; dry connection. Available in multimode and single mode versions. Fully compatible with existing ST hardware. For data processing, telecommunications and local area networks, premise installations, instrumentation and other distribution applications. Low insertion and return loss.



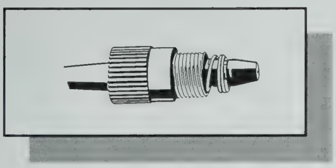
■ **FC.** One piece connector design for easy termination. Compatible with NTT-FC and NTT-D3 hardware. Dry connection with screw type strength member retention. Available in multimode and single mode versions. Applicable for telecommunications and data communications networks, premise installations and instrumentation. Low insertion and return loss.



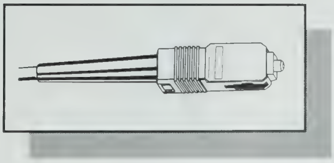
■ **SMA.** Small size connector with SMA coupling nut; dry connection. For use with multimode cables in data communications applications such as local area and data processing networks, premise installations and instrumentation. Low insertion loss. Fully compatible with all existing SMA hardware.



■ **D4.** Compatible with NTT-D4 hardware. Ferrule alignment key for consistent remating. Rugged construction for long life and durability. Low insertion and return loss.



■ **Biconic.** Small size connector with screw thread, cap and spring loaded latching mechanism. Low insertion and return loss. Compatible with all biconic hardware.



■ **SC.** Square design for high packing density. Push-pull operation simplifies connections. Available in single mode and multimode versions. Low insertion and return loss.

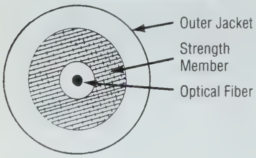
NOTE: Information on connectors is presented for selection assistance only. Belden Wire and Cable does not assume any liability or responsibility for the accuracy of descriptive or performance data herein. Product and performance specifications should be verified with the connector manufacturer.

BitLite® Cables

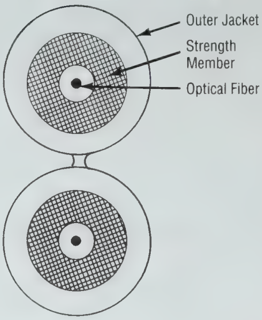
Tight Buffer—Indoor

Fiber Counts	1 & 2
Fiber Sizes	Single Mode, 50, 62.5, 100 micron
Buffer Size	900 microns
Breakout Element Size	3.0 mm
Jackets	PVC, FA
U.L. Listing/NEC	OFNR, OFNP
Strength Members	Kevlar®
Operating Temperature Range	–10°C to +50°C PVC 0°C to +75°C FA
Crush Resistance	1450 lb/inch
Impact Resistance	3.6ft–lbs, 10 impacts
Flexing	1,000 cycles, 22lbs, 2 inch radius
Twist/Bend	1,000 cycles, 22lbs, 50mm radius
Breakout Kit Required	No

Single Fiber



Duplex



Product Description: Belden® BitLite cables are small and flexible cables commonly used as drop cable to the device or to interconnect equipment within a wiring closet. This jumper cordage utilizes the tight buffer breakout style construction for direct connector attachment. The tight buffer construction is more flexible and crush resistant than loose-tube cables.

In BitLite cables, the thermoplastic buffered fiber is concentrically surrounded by a serve of Kevlar yarn for added tensile strength and protection. An outer jacket of Light Gray PVC or Natural Flamarrest completes the cable structure. The duplex cable is a figure 8 or zip-cord type construction for easy termination with single channel fiber optic connectors and the FDDI MIC connector.

BitLite cables are available in standard lengths of 3280 feet (1km) and 6560 feet (2km), subject to a variation of –0 +10%. All put-ups are one piece lengths. Custom lengths are available upon request at no extra charge.

BitLite® Cables

Tight Buffer—Indoor

Single Mode/125/900 Micron (Core/Clad/Buffer)

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.4
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
  Installation: 2
  Long-term application: 1
Strength member: Kevlar•

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
221161 NEC OFNR	1	.118	3.0	6	125	35	PVC
221162 NEC OFNR	2	.118 x .242	3.0 x 6.1	12	250	70	PVC
221811 NEC OFNP	1	.118	3.0	6	125	35	FA
221812 NEC OFNP	2	.118 x .242	3.0 x 6.1	12	250	70	FA

62.5/125/900 Micron (Core/Clad/Buffer)

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
  Installation: 2
  Long-term application: 1
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
225181 NEC OFNR	1	.118	3.0	6	125	35	PVC
225182 NEC OFNR	2	.118 x .242	3.0 x 6.1	12	250	70	PVC
225811 NEC OFNP	1	.118	3.0	6	125	35	FA
225812 NEC OFNP	2	.118 x .242	3.0 x 6.1	12	250	70	FA

50/125/900 Micron (Core/Clad/Buffer)

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
  Installation: 2
  Long-term application: 1
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
227161 NEC OFNR	1	.118	3.0	6	125	35	PVC
227162 NEC OFNR	2	.118 x .242	3.0 x 6.1	12	250	70	PVC
227811 NEC OFNP	1	.118	3.0	6	125	35	FA
227812 NEC OFNP	2	.118 x .242	3.0 x 6.1	12	250	70	FA

100/140/900 Micron (Core/Clad/Buffer)

Product Specifications
Numerical aperture: .29
Maximum attenuation dB/km @ 850/1300nm: 5.0/4.0
Bandwidth MHz-km @ 850/1300nm: 100/200
Minimum bend radius inches:
  Installation: 2
  Long-term application: 1
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
226161 NEC OFNR	1	.118	3.0	6	125	35	PVC
226162 NEC OFNR	2	.118 x .242	3.0 x 6.1	12	250	70	PVC
226811 NEC OFNP	1	.118	3.0	6	125	35	FA
226812 NEC OFNP	2	.118 x .242	3.0 x 6.1	12	250	70	FA

• DuPont trademark.

PVC = Polyvinylchloride
FA = Flamarrest™

LANLite™ Cables
Non-Breakout

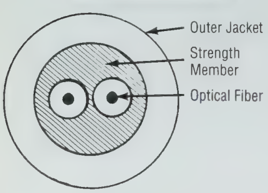
BELDEN

COOPER INDUSTRIES

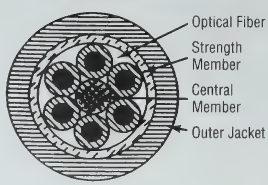
Tight Buffer—Indoor/Outdoor

Fiber Counts	2–12
Fiber Sizes	Single Mode, 50, 62.5 microns
Buffer Size	900 microns
Breakout Element Size	Non-Breakout
Jackets	PVC, FA, FCP
U.L.® Listing/NEC	OFNR, OFNP
Strength Members	Kevlar•
Operating Temperature Range	–10˚C to +50˚C
Crush Resistance	80 lb/inch
Impact Resistance	1.4 ft-lbs, 10 impacts
Flexing	100 cycles, 8.8 lbs, 10 x O.D. Radius
Twist/Bend	100 cycles, 8.8 lbs, 10 x O.D. Radius
Breakout Kit Required	2 fiber No. 229690 4–12 fiber No. 229687

2–Fiber



6–Fiber



Product Description: Belden® LANLite Local Area Network Indoor Trunk cables are designed for indoor applications to provide high bit rate communication between mainframes and building distribution systems. LANLite cables can be used for outdoor applications in a protected environment, such as duct or conduit. The Belden line includes both NEC OFNR rated cables for riser and vertical shaft installations and OFNP rated for use in return air plenums.

The fibers are stranded around a central, non-rigid high tensile strength member, and covered by a Kevlar yarn, which provides impact resistance.

LANLite cables provide the necessary bandwidth capacity to transport all the voice, data, and video signals required in today's evolving automated office/factory environment. The cable's small diameter, light weight, and flexibility provide easy installation and maintenance.

LANLite cables are available in standard lengths of 3280 feet (1km) and 6560 feet (2km), subject to a variation of –0 +10%. All put-ups are one piece lengths. Custom lengths are available upon request at no extra charge. See Color Code chart on page 40.

• DuPont trademark.

PVC = Polyvinylchloride
FCP = Fluorocopolymer
FA = Flamarrest®

LANLite™ Cables
Non-Breakout

Tight Buffer—Indoor/Outdoor

Single Mode/125/900 Micron (Core/Clad/Buffer)

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.5
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: Kevlar•

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550267 NEC OFNR	2	.175	4.4	12	100	14	PVC
550268 NEC OFNR	4	.175	4.4	12	100	14	PVC
550269 NEC OFNR	6	.210	5.3	16	125	19	PVC
550270 NEC OFNR	12	.275	7.0	28	150	33	PVC
221802 NEC OFNP	2	.190	4.8	13	100	14	FA*
550279 NEC OFNP	2	.195	5.0	14	100	14	FCP
550280 NEC OFNP	4	.195	5.0	14	100	14	FCP
550281 NEC OFNP	6	.245	6.2	29	125	19	FCP
550282 NEC OFNP	12	.320	8.1	33	150	33	FCP

50/125/900 Micron (Core/Clad/Buffer)
Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 4.0/1.5
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia.For FCP, 15 x dia.
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550259 NEC OFNR	2	.175	4.4	12	100	14	PVC
550260 NEC OFNR	4	.175	4.4	12	100	14	PVC
550261 NEC OFNR	6	.210	5.3	16	125	19	PVC
550262 NEC OFNR	12	.275	7.0	28	150	33	PVC
227802 NEC OFNP	2	.190	4.8	13	100	14	FA*

50/125/900 Micron (Core/Clad/Buffer) (cont'd.)

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550271 NEC OFNP	2	.195	5.0	14	100	14	FCP
550272 NEC OFNP	4	.195	5.0	14	100	14	FCP
550273 NEC OFNP	6	.245	6.2	29	125	19	FCP
550274 NEC OFNP	12	.320	8.1	33	150	33	FCP

62.5/125/900 Micron (Core/Clad/Buffer)
Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 4.0/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550263 NEC OFNR	2	.175	4.4	12	100	14	PVC
550264 NEC OFNR	4	.175	4.4	12	100	14	PVC
550265 NEC OFNR	6	.210	5.3	16	125	19	PVC
550266 NEC OFNR	12	.275	7.0	28	150	33	PVC
225802 NEC OFNP	2	.190	4.8	13	100	14	FA*
550275 NEC OFNP	2	.195	5.0	14	100	14	FCP
550276 NEC OFNP	4	.195	5.0	14	100	14	FCP
550277 NEC OFNP	6	.245	6.2	29	125	19	FCP
550278 NEC OFNP	12	.320	8.1	33	150	33	FCP

* Flamarrest®-jacketed cables not recommended for long-term outdoor use.

• DuPont trademark.

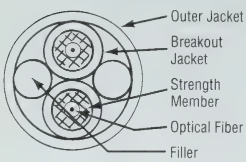
PVC = Polyvinylchloride
FCP = Fluorocopolymer
FA = Flamarrest

BELDEN

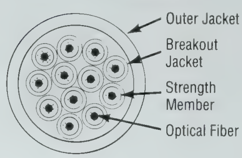
Tight Buffer—Indoor/Outdoor

Fiber Counts	2–24 Riser, 4–12 Plenum
Fiber Sizes	Single Mode, 50, 62.5, 100
Buffer Size	900 microns
Breakout Element Size	2.4 mm
Jackets	PVC, FCP
U.L. Listing/NEC	OFNR, OFNP
Strength Members	Kevlar,• only or FGE with Kevlar
Operating Temperature Range	–20˚C to +80˚C PVC 0˚C to +60˚C Plenum
Crush Resistance	250 lb/inch
Impact Resistance	3.6 ft-lbs, 10 impacts
Flexing	1000 cycles, 22 lbs, 10 x O.D. Radius
Twist/Bend	1000 cycles, 22 lbs, 10 x O.D. Radius
Breakout Kit Required	No

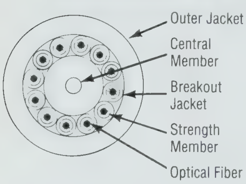
2–Fiber



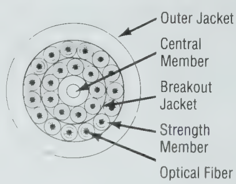
12–Fiber PVC



12–Fiber FCP



24–Fiber



• DuPont trademark.

FGE = Fiberglass epoxy rod
PVC = Polyvinylchloride
FCP = Fluorocopolymer

Product Description: Breakout cables can be used in Local Area Network applications. These cables provide the additional advantage of individually strengthened fibers ready for direct connector attachment. Breakout cables can be used in indoor applications as well as in protected outdoor environments. Each individually jacketed single fiber unit accepts all of the popular connector types on the market today.

Breakout cables are available in standard lengths of 3280 feet (1 km), and 6560 feet (2 km), subject to a variation of –0 +10%. All put-ups are one-piece lengths. Custom lengths are available upon request at no extra charge.

See Color Code chart on page 40.

Tight Buffer—Indoor/Outdoor

Single Mode/125/900 Micron (Core/Clad/Buffer)

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.4
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: FGE/Kevlar•
Subunit dia. mm: 2.4

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000'	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
221302• NEC OFNR	2	.236	6.0	17.0	150	25	PVC
221304• NEC OFNR	4	.285	7.2	31.5	290	90	PVC
221306 NEC OFNR	6	.363	9.2	52.5	380	115	PVC
221308 NEC OFNR	8	.437	11.0	66.0	480	145	PVC
221310 NEC OFNR	10	.506	12.8	108	575	175	PVC
221312• NEC OFNR	12	.473	12.0	76	575	175	PVC
221318 NEC OFNR	18	.583	14.8	133	960	290	PVC
221324 NEC OFNR	24	.676	17.2	180	1250	375	PVC
221864 NEC OFNP	4	.296	7.5	35	290	90	FCP
221866 NEC OFNP	6	.347	8.8	53	535	160	FCP
221868 NEC OFNP	8	.409	10.4	76	630	190	FCP
221863 NEC OFNP	10	.473	12.0	106	1000	300	FCP
221865 NEC OFNP	12	.533	13.5	138	1100	330	FCP

• Kevlar only strength member.

50/125/900 Micron (Core/Clad/Buffer)

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 15 x dia
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: FGE/Kevlar
Subunit dia. mm: 2.4

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000'	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
227302• NEC OFNR	2	.236	6.0	17.0	150	25	PVC
227304• NEC OFNR	4	.285	7.2	31.5	290	90	PVC
227306 NEC OFNR	6	.363	9.2	52.5	380	115	PVC
227308 NEC OFNR	8	.437	11.0	66.0	480	145	PVC
227310 NEC OFNR	10	.506	12.8	108	575	175	PVC
227312• NEC OFNR	12	.473	12.0	76	575	175	PVC
227318 NEC OFNR	18	.583	14.8	133	960	290	PVC
227324 NEC OFNR	24	.676	17.2	180	1250	375	PVC
227864 NEC OFNP	4	.296	7.5	35	290	90	FCP
227866 NEC OFNP	6	.347	8.8	53	535	160	FCP
227868 NEC OFNP	8	.409	10.4	76	630	190	FCP
227863 NEC OFNP	10	.473	12.0	106	1000	300	FCP
227865 NEC OFNP	12	.533	135	138	1100	330	FCP

• Kevlar only strength member.

• DuPont trademark.

PVC = Polyvinylchloride
FCP = Fluorocopolymer
FGE = Fiberglass epoxy rod

Breakout Cables

Tight Buffer—Indoor/Outdoor

62.5/125/900 Micron (Core/Clad/Buffer)

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia
Strength member: FGE/Kevlar•
Subunit dia. mm: 2.4

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
225362* NEC OFNR	2	.236	6.0	17.0	150	25	PVC
225364* NEC OFNR	4	.285	7.2	31.5	290	90	PVC
225366 NEC OFNR	6	.363	9.2	52.5	380	115	PVC
225368 NEC OFNR	8	.437	11.0	66.0	480	145	PVC
225363 NEC OFNR	10	.506	12.9	108	575	175	PVC
225365* NEC OFNR	12	.473	12.0	76	575	175	PVC
225367 NEC OFNR	18	.583	14.8	133	960	290	PVC
225369 NEC OFNR	24	.676	17.2	180	1250	375	PVC
225864 NEC OFNP	4	.296	7.5	35	290	90	FCP
225866 NEC OFNP	6	.347	8.8	53	535	160	FCP
225868 NEC OFNP	8	.409	10.4	76	630	190	FCP
225863 NEC OFNP	10	.473	12.0	106	1000	300	FCP
225865 NEC OFNP	12	.533	13.5	138	1100	330	FCP

* Kevlar only strength member.

100/140/900 Micron (Core/Clad/Buffer)

Product Specifications
Numerical aperture: .29
Maximum attenuation dB/km @ 850/1300nm: 5.0/4.0
Bandwidth MHz-km @ 850/1300nm: 100/200
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: FGE/Kevlar
Subunit dia. mm: 2.4

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
226302* NEC OFNR	2	.236	6.0	17.0	150	25	PVC
226304* NEC OFNR	4	.285	7.2	31.5	290	90	PVC
226306 NEC OFNR	6	.363	9.2	52.5	380	115	PVC
226308 NEC OFNR	8	.437	11.0	66.0	480	145	PVC
226310 NEC OFNR	10	.506	12.9	108	575	175	PVC
226312* NEC OFNR	12	.473	12.0	76	575	175	PVC
226318 NEC OFNR	18	.583	14.8	133	960	290	PVC
226324 NEC OFNR	24	.676	17.2	180	1250	375	PVC
226864 NEC OFNP	4	.296	7.5	45	290	90	FCP
226866 NEC OFNP	6	.347	8.8	53	535	160	FCP
226868 NEC OFNP	8	.409	10.4	76	630	190	FCP
226863 NEC OFNP	10	.473	12.0	106	1000	300	FCP
226865 NEC OFNP	12	.533	13.5	138	1100	330	FCP

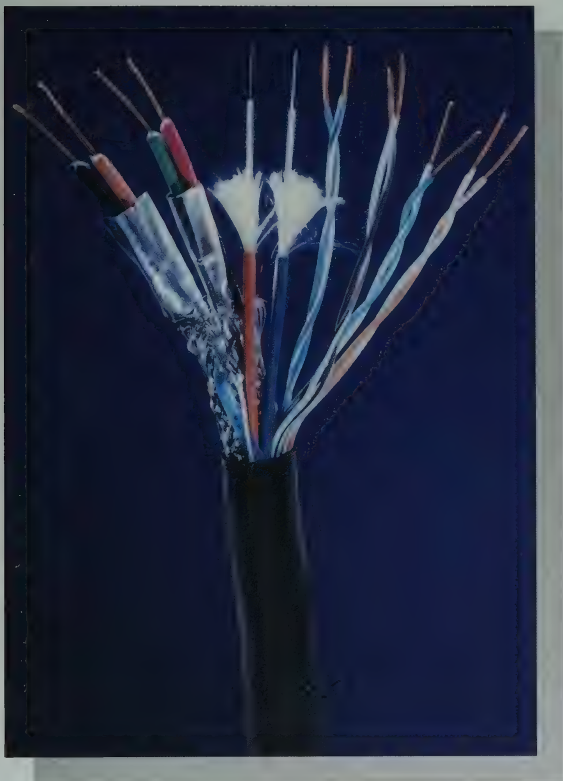
* Kevlar only strength member.

• DuPont trademark.

[illegible] = Polyvinylchloride
[illegible] = Fluorocopolymer
[illegible] Fiberglass epoxy rod

BELDEN

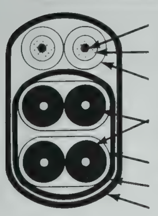
Tight Buffer—Indoor



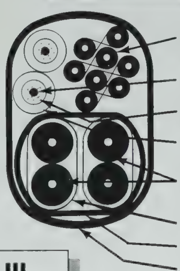
Fiber Counts	2 (to 8)*
Fiber Sizes	62.5 microns, with IBM Type I, II, or III
Buffer Size	900 microns
Breakout Element Size	2.0 mm
Jackets	PVC, FCP
U.L. Listing/NEC	CMR-OF, CMP-OF
Strength Members	Kevlar• (with fiber)
Operating Temperature Range	–10°C to+75°C
Impedance – DGM	150 ohms @ 3-20 Mhz
VGM	105 ohms @ 256 Khz 100 ohms @ 4 Mhz
Attenuation – DGM	22 dB/km @ 4 Mhz 45 dB/km @ 16 Mhz
VGM	7.1 dB/km @ 150 Khz 16.8 dB/km @ 772 Khz
Crosstalk – DGM	–58 dB/km @ 4 Mhz –40 dB/km @ 16 Mhz
VGM	–63 dB/km @ 150 Khz –56 dB/km @ 772 Khz
Breakout Kit Required	No

*Fiber counts are available to 8 fibers.

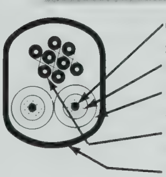
Type I



Type II



Type III



Product Description: Belden® SuperLite cables with a hybrid combination of copper pairs and fiber provide the capability of transmitting telephone voice signals and high speed data within the same cable. This type of hybrid cable design provides the advantage of utilizing current copper technology with the opportunity to upgrade to fiber for future applications.

SuperLite cables are available in standard lengths of 3280 feet (1km) and 6560 feet (2km), subject to a variation of –0 +10%. All put-ups are one piece lengths. Custom lengths are available upon request at no extra charge.

• DuPont trademark.
FCP = Fluorocopolymer
PVC = Polyvinylchloride

SuperLite™ Cables

Tight Buffer—Indoor

Type I with 2–62.5 Breakouts

Fiber elements meet IBM Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 4.0
Long-term application: 4.0
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
229688 **NEC** CMR-OF	2	.390 x .445	9.9 x 11.3	70	120	40	PVC
229888 **NEC** CMP-OF	2	.380 x .435	9.7 x 11.0	65	120	40	FCP

Type II with 2–62.5 Breakouts

Fiber elements meet IBM Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 5.0
Long-term application: 5.0
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
229689 **NEC** CMR-OF	2	.395 x .560	10.0 x 14.2	99	146	50	PVC
229889 **NEC** CMP-OF	2	.385 x .550	9.8 x 14.0	86	146	50	FCP

NOTE: Up to 8 fibers available.

Type III with 2–62.5 Breakouts

Fiber elements meet IBM Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 3.0
Long-term application: 3.0
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
229154 **NEC** CMR-OF	2	.250	6.4	32	120	40	PVC
229855 **NEC** CMP-OF	2	.240	6.1	31	120	40	FCP

® DuPont trademark.

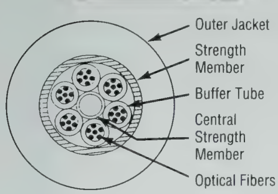
PVC = Polyvinylchloride
FCP = Fluorocopolymer

Interbuilding Trunk Cables Multifiber Per Tube (MFPT)

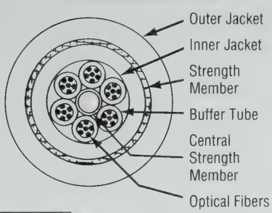
Loose Buffer—Outdoor

Fiber Counts	1–72
Fiber Sizes	Single Mode, 50, 62.5 microns
Buffer Tube Size	2.0 mm ≤ 6 fibers 2.5 mm > 6 fibers
Breakout Element Size	N/A
Jackets	PE
U.L. Listing/NEC	N/A
Strength Members	Kevlar• only or FGE with Kevlar
Operating Temperature Range	–40°C to +80°C
Crush Resistance	125 lb/inch–Single Jacket 250 lb/inch–Armored + Heavy Duty
Impact Resistance	3.3 ft-lbs, 25 impacts
Flexing	25 cycles, 12 lbs, 20 x O.D. Radius
Twist/Bend	25 cycles, 12 lbs, 20 x O.D. Radius
Breakout Kit Required	229615 for 221402, 225412, 227412. 229865 for 4 and 6 fiber, single fiber per tube.

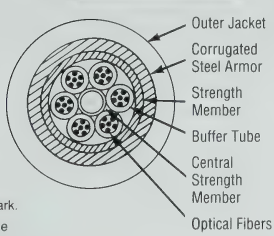
Single Jacket



Heavy Duty



Armored



• DuPont trademark.

PE = Polyethylene
FGE = Fiberglass Epoxy Rod
MFPT = Multifiber per tube

Product Description: Belden's interbuilding trunk cables are ideally suited for Wide Area Networks, multi-building interconnection, and broadcast and video applications such as CATV supertrunk and satellite uplink/downlinks. The multifiber per tube (MFPT) design consists of 1 to 72 fibers contained in loose, gel-filled buffer tubes. This family of cables is available in armored, dielectric, and double jacketed versions.

See Color Code chart and Buffer Tube Configuration chart on page 40.

COOPER INDUSTRIES BELDEN

Interbuilding Trunk Cables
Multifiber Per Tube (MFPT)

Loose Buffer—Outdoor

Single Mode/125/250 Micron (Core/Clad/Coating) All Dielectric—MFPT

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.4
Maximum dispersion ps/nm-km @ 1310/1550 nm: 2.8/18
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar•
4 and 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
221704	4	.374	9.5	50	600	140	PE
221706	6	.374	9.5	50	600	140	PE
221708	8	.435	11.0	70	600	140	PE
221710	10	.435	11.0	70	600	140	PE
221712	12	.435	11.0	70	600	140	PE
221716	16	.435	11.0	70	600	140	PE
221718	18	.435	11.0	70	600	140	PE
221724	24	.435	11.0	70	600	140	PE
221736	36	.435	11.0	70	600	140	PE
221748	48	.490	12.4	85	600	140	PE
221760	60	.565	14.4	105	600	140	PE
221772	72	.630	16.0	125	600	140	PE

Single Mode/125/250 Micron (Core/Clad/Coating) Armored—MFPT

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.4
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 15 x dia.
Strength member: FGE/Kevlar
Armor: Corrugated steel
2 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
221502	2	.453	11.5	90	600	140	PE
221504	4	.453	11.5	90	600	140	PE
221506	6	.453	11.5	90	600	140	PE
221508	8	.515	13.0	120	600	140	PE
221510	10	.515	13.0	120	600	140	PE
221512	12	.515	13.0	120	600	140	PE
221516	16	.515	13.0	120	600	140	PE
221518	18	.515	13.0	120	600	140	PE
221524	24	.515	13.0	120	600	140	PE
221536	36	.515	13.0	120	600	140	PE
221548	48	.570	14.5	140	600	140	PE
221560	60	.650	16.5	175	600	140	PE
221572	72	.710	18.0	195	600	140	PE

Single Mode/125/250 Micron (Core/Clad/Coating) All Dielectric Heavy Duty—MFPT

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.5/0.4
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar
1 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Inner Jacket Outer Jacket
221411◆	1	.264	6.7	25	200	40	PVC PE
221432◆	2	.244 x .394	6.2 x 10.0	40	400	80	PVC PE
221402◆	2	.405	10.3	60	400	80	PVC PE
221404	4	.465	11.8	70	600	180	PE PE
221406	6	.465	11.8	70	600	180	PE PE
221408	8	.525	13.3	95	600	180	PE PE
221410	10	.525	13.3	95	600	180	PE PE
221412	12	.525	13.3	95	600	180	PE PE
221416	16	.525	13.3	95	600	180	PE PE
221418	18	.525	13.3	95	600	180	PE PE
221424	24	.525	13.3	95	600	180	PE PE
221436	36	.525	13.3	95	600	180	PE PE
221448	48	.590	15.0	115	600	180	PE PE
221460	60	.655	16.6	135	600	180	PE PE
221472	72	.730	18.5	160	600	180	PE PE

◆ Kevlar only strength member.

• DuPont trademark.

PVC = Polyvinylchloride
PE = Polyethylene
FGE = Fiberglass epoxy rod

Interbuilding Trunk Cables Multifiber Per Tube (MFPT)

Loose Buffer—Outdoor

50/125/250 Micron (Core/Clad/Coating) All Dielectric—MFPT

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.0/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar*
4 and 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000'	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
227714	4	.374	9.5	50	600	140	PE
227716	6	.374	9.5	50	600	140	PE
227718	8	.435	11.0	70	600	140	PE
227713	10	.435	11.0	70	600	140	PE
227715	12	.435	11.0	70	600	140	PE
227717	18	.435	11.0	70	600	140	PE
227724	24	.435	11.0	70	600	140	PE
227736	36	.435	11.0	70	600	140	PE
227748	48	.490	12.4	85	600	140	PE
227760	60	.565	14.4	105	600	140	PE
227772	72	.630	16.0	125	600	140	PE

50/125/250 Micron (Core/Clad/Coating) Armored—MFPT

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.0/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 15 x dia.
Strength member: FGE/Kevlar
Armor: Corrugated steel
2 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000'	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
227502	2	.453	11.5	90	600	140	PE
227504	4	.453	11.5	90	600	140	PE
227506	6	.453	11.5	90	600	140	PE
227508	8	.515	13.0	120	600	140	PE
227510	10	.515	13.0	120	600	140	PE
227512	12	.515	13.0	120	600	140	PE
227518	18	.515	13.0	120	600	140	PE
227524	24	.515	13.0	120	600	140	PE
227536	36	.515	13.0	120	600	140	PE
227548	48	.570	14.5	140	600	140	PE
227560	60	.650	16.5	175	600	140	PE
227572	72	.710	18.0	195	600	140	PE

50/125/250 Micron (Core/Clad/Coating) All Dielectric Heavy Duty—MFPT

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.0/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar
1 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./1000'	Maximum Recommended Load—Lbs.		Inner Jacket	Outer Jacket
		Inch	mm		Installation	Long-Term Application		
227411•	1	.264	6.7	25	300	40	PVC	PE
229657•	2	.244 x .394	6.2 x 10.0	40	500	80	PVC	PE
227412•	2	.405	10.3	60	600	80	PVC	PE
227414	4	.465	11.8	70	600	180	PE	PE
227416	6	.465	11.8	70	600	180	PE	PE
227418	8	.525	13.3	95	600	180	PE	PE
227413	10	.525	13.3	95	600	180	PE	PE
227415	12	.525	13.3	95	600	180	PE	PE
227417	18	.525	13.3	95	600	180	PE	PE
227424	24	.525	13.3	95	600	180	PE	PE
227436	36	.525	13.3	95	600	180	PE	PE
227448	48	.590	15.0	115	600	180	PE	PE
227460	60	.655	16.6	135	600	180	PE	PE
227472	72	.730	18.5	160	600	180	PE	PE

• Kevlar only strength member.

* DuPont trademark.

PVC = Polyvinylchloride
PE = Polyethylene
FGE = Fiberglass epoxy rod
MFPT = Multifiber per tube

Interbuilding Trunk Cables
Multifiber Per Tube (MFPT)

COOPER INDUSTRIES BELDEN

Loose Buffer—Outdoor

62.5/125/250 Micron (Core/Clad/Coating) All Dielectric—MFPT

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar•
4 and 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
225714	4	.374	9.5	50	600	140	PE
225716	6	.374	9.5	50	600	140	PE
225718	8	.435	11.0	70	600	140	PE
225713	10	.435	11.0	70	600	140	PE
225715	12	.435	11.0	70	600	140	PE
225717	18	.435	11.0	70	600	140	PE
225724	24	.435	11.0	70	600	140	PE
225736	36	.435	11.0	70	600	140	PE
225748	48	.490	12.4	85	600	140	PE
225760	60	.565	14.7	105	600	140	PE
225772	72	.630	16.0	125	600	140	PE

62.5/125/250 Micron (Core/Clad/Coating) Armored—MFPT

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 15 x dia.
Strength member: FGE/Kevlar
Armor: Currugated steel
2 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
225502	2	.453	11.5	90	600	140	PE
225504	4	.453	11.5	90	600	140	PE
225506	6	.453	11.5	90	600	140	PE
225508	8	.575	13.0	120	600	140	PE
225510	10	.515	13.0	120	600	140	PE
225512	12	.515	13.0	120	600	140	PE
225518	18	.515	13.0	120	600	140	PE
225524	24	.515	13.0	120	600	140	PE
225536	36	.515	13.0	120	600	140	PE
225548	48	.570	14.5	140	600	140	PE
225560	60	.650	16.5	175	600	140	PE
225572	72	.710	18.0	195	600	140	PE

62.5/125/250 Micron (Core/Clad/Coating) All Dielectric Heavy Duty—MFPT

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE/Kevlar
1 thru 6 fiber cables are single fiber per tube.

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Inner Jacket / Outer Jacket
225411•	1	.264	6.7	25	300	40	PVC / PE
225432•	2	.244 x .394	6.2 x 10.0	35	500	80	PVC / PE
225412•	2	.405	10.3	60	600	80	PVC / PE
225414	4	.465	11.8	70	600	180	PE / PE
225416	6	.465	11.8	70	600	180	PE / PE
225418	8	.525	13.3	95	600	180	PE / PE
225413	10	.525	13.3	95	600	180	PE / PE
225415	12	.525	13.3	95	600	180	PE / PE
225417	18	.525	13.3	95	600	180	PE / PE
225424	24	.525	13.3	95	600	180	PE / PE
225436	36	.525	13.3	95	600	180	PE / PE
225448	48	.590	15.0	115	600	180	PE / PE
225460	60	.655	16.6	135	600	180	PE / PE
225472	72	.730	18.5	160	600	180	PE / PE

• Kevlar only strength member.

• DuPont trademark.

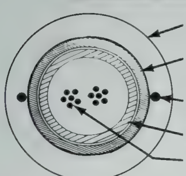
PVC = Polyvinylchloride
PE = Polyethylene
FGE = Fiberglass epoxy rod
MFPT = Multifiber per tube

BELDEN

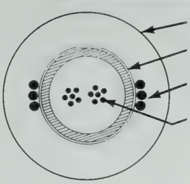
Loose Buffer—Outdoor

Fiber Counts	4–72
Fiber Sizes	Single Mode
Buffer Tube Size	4–48 fiber .240" 60 & 72 fiber .310"
Breakout Element Size	N/A
Jackets	PE
U.L. Listing/NEC	N/A
Strength Members	FGE/Steel
Operating Temperature Range	–40°C to +70°C
Crush Resistance	Armored – 125 lb/inch Non-Armored – 250 lb/inch
Impact Resistance	3.3 ft-lbs, 25 impacts
Flexing	25 cycles, 12 lbs, 10 x O.D. Radius
Twist/Bend	25 cycles, 12 lbs, 10 x O.D. Radius
Breakout Kit Required	N/A

Armored



All Dielectric



Product Description: Belden's Interbuilding Trunk cables are ideally suited for Wide Area Networks, multi-building interconnection, and broadcast and video applications such as CATV supertrunk and satellite uplink/downlinks. The bundled fiber design consists of 4 to 72 single mode fibers bundled in groups of 6 or 12 contained within one, gel-filled polyethylene core tube. Cables containing 36 fibers and less utilize six fiber bundles. Cables with fiber counts of 48, 60, and 72 consist of groups of 12 fibers bundled loosely together with a spirally applied binder.

See Color Code chart on page 40.

• DuPont trademark.
PE = Polyethylene
FGE = Fiberglass epoxy rod

COOPER INDUSTRIES BELDEN

Loose Buffer—Outdoor

Single Mode/125/250 Micron (Core/Clad/Coating) All Dielectric—Bundled Fiber

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.4/0.3
Maximum dispersion ps/nm km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: FGE

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
551704	4	.490	12.4	90	600	180	PE
551706	6	.490	12.4	90	600	180	PE
551708	8	.490	12.4	90	600	180	PE
551710	10	.490	12.4	90	600	180	PE
551712	12	.490	12.4	90	600	180	PE
551716	16	.490	12.4	90	600	180	PE
551718	18	.490	12.4	90	600	180	PE
551724	24	.490	12.4	90	600	180	PE
551736	36	.490	12.4	90	600	180	PE
551748	48	.490	12.4	90	600	180	PE
551760	60	.590	15.0	115	600	180	PE
551772	72	.590	15.0	115	600	180	PE

Single Mode/125/250 Micron (Core/Clad/Coating) Armored—Bundled Fiber

Product Specifications
Maximum attenuation dB/km @ 1310/1550nm: 0.4/0.3
Maximum dispersion ps/nm-km @ 1310/1550nm: 2.8/18
Minimum bend radius inches:
Installation: 20 x dia.
Long-term application: 10 x dia.
Strength member: Steel
Armor: Corrugated steel

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
551504	4	.490	12.4	105	600	180	PE
551506	6	.490	12.4	105	600	180	PE
551508	8	.490	12.4	105	600	180	PE
551510	10	.490	12.4	105	600	180	PE
551512	12	.490	12.4	105	600	180	PE
551516	16	.490	12.4	105	600	180	PE
551518	18	.490	12.4	105	600	180	PE
551524	24	.490	12.4	105	600	180	PE
551536	36	.490	12.4	105	600	180	PE
551548	48	.490	12.4	105	600	180	PE
551560	60	.590	15.0	145	600	180	PE
551572	72	.590	15.0	145	600	180	PE

FGE = Fiberglass epoxy rod
PE = Polyethylene

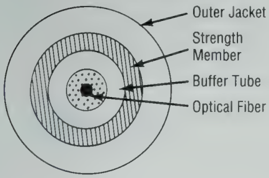
BELDEN

COOPER INDUSTRIES

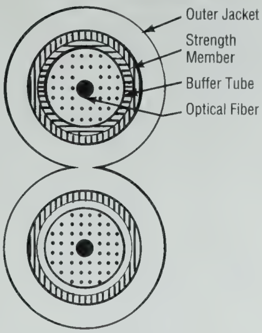
Loose Buffer—Indoor

Fiber Counts	1 & 2
Fiber Sizes	50, 62.5, 100 microns
Buffer Tube Size	2.0 mm
Breakout Element Size	3.8 mm
Jackets	PVC
U.L. Listing/NEC	OFN
Strength Members	Kevlar•
Operating Temperature Range	–10°C to +55°C
Crush Resistance	250 lb/inch
Impact Resistance	1.1 ft-lbs, 50 impacts
Flexing	1000 cycles, 22 lbs 2 inch Radius
Twist/Bend	1000 cycles, 22 lbs 2 inch Radius
Breakout Kit Required	No

Single Fiber



Duplex



Product Description: Belden's General Purpose Cables utilize a loose buffer tube construction and are suitable for indoor installation in duct, tray, or conduit. The individual fibers are enclosed in gel-filled plastic buffer tubes maintaining an optimal amount of excess fiber in each tube. This minimizes the cable's attenuation losses caused by microbending or expansion and contraction.

This product is designed for rugged installation in indoor or protected environments such as ducts. While short lengths of this cable type can be exposed to wide temperature range variations, other cable designs with different strength members and jackets are available for outdoor aerial and buried installations. The 50, 62.5, and 100 micron core fibers are all glass graded index construction.

General purpose cables are available in standard lengths of 3280 feet (1 km) and 6560 feet (2 km), subject to a variation of –0 +10%. All put-ups are one piece lengths. Custom lengths are available upon request at no extra charge.

• DuPont trademark.
PVC = Polyvinylchloride

All sales of Belden products are subject to Belden's standard terms and conditions of sale.

All printing errors are subject to correction.

Although Belden makes every effort to ensure the accuracy of specifications at the time of this publication, specifications for products described in this publication are subject to change without notice. Contact the Belden Wire and Cable Product Engineering Group for the most current information at **1-317-983-5200.**

Loose Buffer—Indoor

50/125/250 Micron (Core/Clad/Coating)

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .20
Maximum attenuation dB/km @ 850/1300nm: 3.0/1.0
Bandwidth MHz-km @ 850/1300nm: 500/500
Minimum bend radius inches:
Installation: 4
Long-term application: 2
Strength member: Kevlar*
Subunit dia. mm: 2.0

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
227201 NEC OFN	1	.150	3.8	8.5	150	10	PVC
227202 NEC OFN	2	.150 x .315	3.8 x 8.0	17	250	20	PVC

62.5/125/250 Micron (Core/Clad/Coating)

Meets IBM 3044 Channel Extender and FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 4
Long-term application: 2
Strength member: Kevlar
Subunit dia. mm: 2.0

Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
225201 NEC OFN	1	.150	3.8	8.5	150	10	PVC
225202 NEC OFN	2	.150 x .315	3.8 x 8.0	17	250	20	PVC

100/140/250 Micron (Core/Clad/Coating)

Product Specifications
Numerical aperture: .29
Maximum attenuation dB/km @ 850/1300nm: 5.0/4.0
Bandwidth MHz-km @ 850/1300nm: 100/200
Minimum bend radius inches:
Installation: 4
Long-term application: 2
Strength member: Kevlar
Subunit dia. mm: 2.0

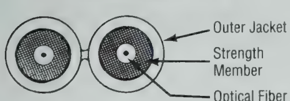
Trade No. NEC Type	No. of Fibers	Outer Diameter		Wt. Lbs./ 1000′	Maximum Recommended Load—Lbs.		Outer Jacket
		Inch	mm		Installation	Long-Term Application	
226021 NEC OFN	1	.150	3.8	8..5	150	10	PVC
226022 NEC OFN	2	.150 x .315	3.8 x 8.0	17	250	20	PVC

* DuPont trademark.
PVC =Polyvinylchloride

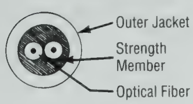
Tight Buffer

Fiber Counts	2–12
Fiber Sizes	62.5 microns
Buffer Size	900 microns
Breakout Element Size	2.0 mm
Jackets	PVC, FCP
U.L. Listing/NEC	OFNR, OFNP
Strength Members	Kevlar,[•] FGE
Operating Temperature Range	–10°C to +55°C
Crush Resistance	80 lb/inch
Impact Resistance	3.3 ft-lbs, 20 impacts
Flexing	100 cycles, 8.8 lbs 10 x O.D. Radius
Twist/Bend	100 cycles, 8.8 lbs 10 X O.D. Radius
Breakout Kit Required	229690 for 2–fiber round jumper. 229687 for Light Duty cables.

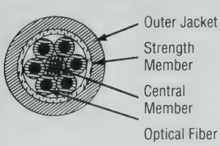
2-Fiber Zip Jumper



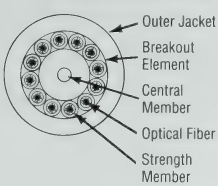
2-Fiber Round Jumper



Light Duty



Heavy Duty



Product Description: These cables provide a non-proprietary, open wiring system architecture for an all-fiber network, from the backbone to desktop. They can be used for a full range of fiber optic LANs, including Ethernet (IEEE 802.3), Token Ring (IEEE 802.5), and FDDI. Complies with the evolving EIA-TR 41.8 Building Wiring Standard. Available in 62.5 micron-size in duplex, LANLite™ or Heavy-Duty Breakout styles.

DECconnect cables are available in standard lengths of 3280 feet (1km) and 6560 feet (2km), subject to a variation of –0 +10%. All put-ups are one piece lengths. Custom lengths are available upon request at no extra charge.

See Color Code chart on page 40.

• DuPont trademark.
✧ Digital Equipment Corporation trademark.
PVC = Polyvinylchloride
FCP = Fluorocpolymer
FGE = Fiberglass epoxy rod

BELDEN COOPER INDUSTRIES

Tight Buffer

62.5/125/900 Micron (Core/Clad/Buffer) Zipcord Jumper

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 2
Long-term application: 1
Strength member: Kevlar•

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550311 NEC OFNR	2	.118 x .242	3.0 x 6.1	12	240	70	PVC

62.5/125/900 Micron (Core/Clad/Buffer) Round Jumper

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 3.0
Long-term application: 1.5
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550312 NEC OFNR	2	.175	4.4	12	100	14	PVC

62.5/125/900 Micron (Core/Clad/Buffer) Light-Duty—(LANLite) Non-Breakout

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: Kevlar

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550292 NEC OFNR	4	.175	4.4	12	100	14	PVC
550308 NEC OFNR	6	.210	5.3	16	125	19	PVC
550294 NEC OFNR	12	.275	7.0	28	150	33	PVC

62.5/125/900 Micron (Core/Clad/Buffer) Heavy-Duty (Breakout)

Meets FDDI Optical Specifications

Product Specifications
Numerical aperture: .275
Maximum attenuation dB/km @ 850/1300nm: 3.5/1.0
Bandwidth MHz-km @ 850/1300nm: 160/500
Minimum bend radius inches:
Installation: 15 x dia.
Long-term application: 10 x dia. For FCP, 15 x dia.
Strength member: FGE/Kevlar
Subunit dia. mm: 2.0

Trade No. NEC Type	No. of Fibers	Outer Diameter Inch	Outer Diameter mm	Wt. Lbs./1000'	Maximum Recommended Load—Lbs. Installation	Maximum Recommended Load—Lbs. Long-Term Application	Outer Jacket
550313 NEC OFNR	4	.245	6.2	32	240	70	PVC
550315 NEC OFNR	6	.315	8.0	38	535	160	PVC
550317 NEC OFNR	12	.479	12.1	101	1100	330	PVC
550314 NEC OFNP	4	.233	5.9	28	240	70	FCP
550316 NEC OFNP	6	.288	7.3	41	535	160	FCP
550318 NEC OFNP	12	.447	11.3	101	1100	330	FCP

DEC/Belden Cross Reference

DEC	Belden
17-02492-01	550311
17-02377-01	550312
17-02433-01	550292
17-02539-01	550308
17-02536-01	550294
17-02490-01	550313
17-02541-01	550315
17-02534-01	550317
17-02491-01	550314
17-02540-01	550316
17-02535-01	550318

* Digital Equipment Corporation trademark.
• DuPont trademark.

PVC = Polyvinylchloride
FCP = Fluorocopolymer
FGE = Fiberglass epoxy rod

Connectorized Cable Assemblies

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Belden fiber optic cables can be cut to any length desired and terminated at one or both ends with the connector required for your application. Connector choices include:

- Siemens FDDI-MIC Connector (AMP, AT&T and Molex also available)
- ST-Compatible
- SMA
- Biconic
- FC
- D4
- SC

The cable assemblies are ready for direct connection to their mating components and feature 100% optical attenuation testing. Maximum insertion loss is 2.0 dB per assembly. Cable attenuation is not included in the insertion loss value.

Belden assemblies utilize a seven digit code.

_ _ _ _ _ _ _
1 2 3 4 5 6 7

1–5: MODIFIED CABLE CODE
6: INNER END CONNECTOR
7: OUTER END CONNECTOR

Connector Code Suffix	Designation
Amp Simplex	A
Biconic	B
FC	C
906 Style Steel SMA	D
906 Style Ceramic SMA	E
FDDI-MIC	F
905 Style Steel SMA	G
905 Style Ceramic SMA	H
IBM Duplex	I
	J
D4	K
SC	L
Mini-BNC	M
No Connectors	N
	O
	P
	Q
	R
ST-Compatible Steel	S
ST-Compatible Ceramic	T
	U
	V
	W
	X
	Y
	Z

The following is a guide for matching your cable assembly requirements to a Belden assembly code number. Refer to the example below, which uses Belden cable code number 225182 with ceramic ST-compatible connectors on the inner end and the FDDI connector on the outer end.

Cable Code Number 0 2 2 5 1 8 2

***Step 1.* Positions 1–5 MODIFY THE CABLE CODE**

Delete the first two digits from the cable code number. Move the remaining digits two places to the left. The last two positions will be blank and ready for step 2.

Cable Code Number ~~0~~ ~~2~~ 2 5 1 8 2

Modified Cable Code 2 5 1 8 2 _ _

***Step 2.* Position 6 INNER END CONNECTOR**

To find position six of the assembly code number, refer to the designation column in the table at left. Locate the connector code suffix that corresponds with the ST-compatible ceramic designation and enter the suffix (T) in position six. If a connector is not required on the inner end, position six will be an "N".

Assembly Code Number 2 5 1 8 2 T _

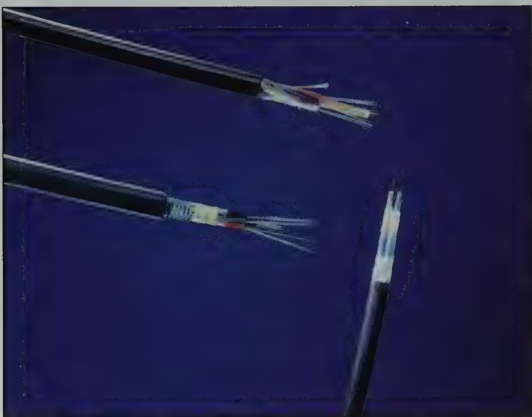
***Step 3.* Position 7 OUTER END CONNECTOR**

To find position seven of the assembly code number, locate the connector code suffix corresponding to the FDDI-MIC connector and enter the suffix (F) in position seven. If a connector is not required on the outer end, position seven will be an "N".

Assembly Code Number 2 5 1 8 2 T F

The Belden assembly code number for this example is **25182TF**.

For further assistance or to order your Belden fiber optic cable assembly call **1-800-BELDEN-1**.



Loose Buffer Breakout Kits

Permits the separation and protection of individual fiber elements so that they may be routed to individual equipment locations. Kits contain all the materials necessary for installation on 2 to 6 fiber cables. Effectively creates a single fiber cable with integral strength member for each fiber in the multifiber cable. Individual connectors may then be attached to each of the breakout kit's subcables.

Kit No. 229615	For 221402, 225412, 227412
Kit No. 229865	For 4 and 6 fiber, single fiber per tube

Tight Buffer Breakout Kits

Permits the direct connectorization of Belden® LANLite™ cables converting them to breakouts. LANLite tight buffer breakout kits include materials to effectively strengthen each single fiber element for direct connector attachment without further protection.

Kit No. 229690	For 550259, 550263, 550267
Kit No. 229687	For 4–12 fiber LANLite

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Tight Buffer Constructions

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz-km) @850nm, 1300nm	Materials: Outer Jacket	Materials: Inner Jacket	Materials: Strength Member
BitLite®								
221161	OFNR	11	Single Mode	1	0.5/2.8,0.4/18 #	PVC	—	K
221811	OFNP	11		1		FA	—	K
221162	OFNR	11		2		PVC	—	K
221812	OFNP	11		2		FA	—	K
227161	OFNR	11	50/125-FDDI	1	3.5/500,1.0/500	PVC	—	K
227811	OFNP	11		1		FA	—	K
227162	OFNR	11		2		PVC	—	K
227812	OFNP	11		2		FA	—	K
225181	OFNR	11	62.5/125-FDDI	1	3.5/160,1.0/500	PVC	—	K
225811	OFNP	11		1		FA	—	K
225182	OFNR	11		2		PVC	—	K
225812	OFNP	11		2		FA	—	K
226161	OFNR	11	100/140	1	5.0/100,4.0/200	PVC	—	K
226811	OFNP	11		1		FA	—	K
226162	OFNR	11		2		PVC	—	K
226812	OFNP	11		2		FA	—	K
LANLite™								
550267	OFNR	13	Single Mode	2	0.5/2.8,0.5/18 #	PVC	—	K
550268	OFNR	13		4		PVC	—	K
550269	OFNR	13		6		PVC	—	K
550270	OFNR	13		12		PVC	—	K
221802	OFNP	13		2		FA	—	K
550279	OFNP	13		2		FCP	—	K
550280	OFNP	13		4		FCP	—	K
550281	OFNP	13		6		FCP	—	K
550282	OFNP	13		12		FCP	—	K
550259	OFNR	13	50/125-FDDI	2	4.0/500,1.5/500	PVC	—	K
550260	OFNR	13		4		PVC	—	K
550261	OFNR	13		6		PVC	—	K
550262	OFNR	13		12		PVC	—	K
227802	OFNP	13		2		FA	—	K
550271	OFNP	13		2		FCP	—	K
550272	OFNP	13		4		FCP	—	K
550273	OFNP	13		6		FCP	—	K
550274	OFNP	13		12		FCP	—	K
550263	OFNR	13	62.5/125-FDDI	2	4.0/160,1.0/500	PVC	—	K
550264	OFNR	13		4		PVC	—	K
550265	OFNR	13		6		PVC	—	K
550266	OFNR	13		12		PVC	—	K
225802	OFNP	13		2		FA	—	K
550275	OFNP	13		2		FCP	—	K
550276	OFNP	13		4		FCP	—	K
550277	OFNP	13		6		FCP	—	K
550278	OFNP	13		12		FCP	—	K

PU = Polyurethane
PE = Polyethylene
PVC = Polyvinylchloride
FCP = Fluorocopolymer
FGE = Fiberglass Epoxy Rod
K = Kevlar

FA = Flamarrest®
MFPT = Multifiber Per Tube
OFN = Vertical Tray Listed
OFNR = Riser Listed
OFNP = Plenum Listed
# = Attenuation/dispersion (dB/km / ps/nm-km) @ 1310 nm, 1550 nm

Tight Buffer Constructions (cont.)

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz–km) @850nm, 1300nm	Materials: Outer Jacket	Materials: Inner Jacket	Materials: Strength Member
Breakout Cables								
221302	OFNR	15	Single Mode	2	0.5/2.8,0.4/18 #	PVC	PVC	K
221304	OFNR	15		4		PVC	PVC	K
221864	OFNP	15		4		FCP	FCP	FGE/K
221306	OFNR	15		6		PVC	PVC	FGE/K
221866	OFNP	15		6		FCP	FCP	FGE/K
221308	OFNR	15		8		PVC	PVC	FGE/K
221868	OFNP	15		8		FCP	FCP	FGE/K
221310	OFNR	15		10		PVC	PVC	FGE/K
221863	OFNP	15		10		FCP	FCP	FGE/K
221312	OFNR	15		12		PVC	PVC	K
221865	OFNP	15		12		FCP	FCP	FGE/K
221318	OFNR	15		18		PVC	PVC	FGE/K
221324	OFNR	15		24		PVC	PVC	FGE/K
227302	OFNR	15	50/125-FDDI	2	3.5/500,1.0/500	PVC	PVC	K
227304	OFNR	15		4		PVC	PVC	K
227864	OFNP	15		4		FCP	FCP	FGE/K
227306	OFNR	15		6		PVC	PVC	FGE/K
227866	OFNP	15		6		FCP	FCP	FGE/K
227308	OFNR	15		8		PVC	PVC	FGE/K
227868	OFNP	15		8		FCP	FCP	FGE/K
227310	OFNR	15		10		PVC	PVC	FGE/K
227863	OFNP	15		10		FCP	FCP	FGE/K
227312	OFNR	15		12		PVC	PVC	K
227865	OFNP	15		12		FCP	FCP	FGE/K
227318	OFNR	15		18		PVC	PVC	FGE/K
227324	OFNR	15		24		PVC	PVC	FGE/K
225362	OFNR	16	62.5/125-FDDI	2	3.5/160,1.0/500	PVC	PVC	K
225364	OFNR	16		4		PVC	PVC	K
225864	OFNP	16		4		FCP	FCP	FGE/K
225366	OFNR	16		6		PVC	PVC	FGE/K
225866	OFNP	16		6		FCP	FCP	FGE/K
225368	OFNR	16		8		PVC	PVC	FGE/K
225868	OFNP	16		8		FCP	FCP	FGE/K
225363	OFNR	16		10		PVC	PVC	FGE/K
225863	OFNP	16		10		FCP	FCP	FGE/K
225365	OFNR	16		12		PVC	PVC	K
225865	OFNP	16		12		FCP	FCP	FGE/K
225367	OFNR	16		18		PVC	PVC	FGE/K
225369	OFNR	16		24		PVC	PVC	FGE/K
226302	OFNR	16	100/140	2	5.0/100,4.0/200	PVC	PVC	K
226304	OFNR	16		4		PVC	PVC	K
226864	OFNP	16		4		FCP	FCP	FGE/K
226306	OFNR	16		6		PVC	PVC	FGE/K
226866	OFNP	16		6		FCP	FCP	FGE/K
226308	OFNR	16		8		PVC	PVC	FGE/K
226868	OFNP	16		8		FCP	FCP	FGE/K
226310	OFNR	16		10		PVC	PVC	FGE/K
226863	OFNP	16		10		FCP	FCP	FGE/K
226312	OFNR	16		12		PVC	PVC	K
226865	OFNP	16		12		FCP	FCP	FGE/K
226318	OFNR	16		18		PVC	PVC	FGE/K
226324	OFNR	16		24		PVC	PVC	FGE/K
SuperLite™								
229688	CMR-OF	18	62.5/125–FDDI	2	3.5/160, 1.0/500	PVC	—	K
229888	CMP-OF	18		2		FCP	—	K
229689	CMR-OF	18		2		PVC	—	K
229889	CMP-OF	18		2		FCP	—	K
229154	CMR-OF	18		2		PVC	—	K
229855	CMP-OF	18		2		FCP	—	K

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K = Kevlar

FA = Flamarrest®
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OFN = Vertical Tray Listed
OFNR = Riser Listed
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# = Attenuation/dispersion (dB/km / ps/nm-km) @ 1310 nm, 1550 nm

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Tight Buffer Constructions (cont.)

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz–km) @850nm, 1300nm	Materials Outer Jacket	Inner Jacket	Strength Member
DECconnect								
Zip Cord								
550311	OFNR	28	62.5/125-FDDI	2	3.5/160,1.0/500	PVC	—	K
LanLite Non-Breakout								
550312	OFNR	28	62.5/125-FDDI	2	3.5/160,1.0/500	PVC	—	K
Heavy Duty Breakout								
550313	OFNR	28	62.5/125-FDDI	4	3.5/160,1.0/500	PVC	—	FGE/K
550314	OFNP	28		4		FCP	—	FGE/K
550315	OFNR	28		6		PVC	—	FGE/K
550316	OFNP	28		6		FCP	—	FGE/K
550317	OFNR	28		12		PVC	—	FGE/K
550318	OFNP	28		12		FCP	—	FGE/K
LanLite Light Duty								
550292	OFNR	28	62.5/125-FDDI	4	3.5/160,1.0/500	PVC	—	K
550308	OFNR	28		6		PVC	—	K
550294	OFNR	28		12		PVC	—	K

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OFNR = Riser Listed
OFNP = Plenum Listed
\# = Attenuation/dispersion (dB/km / ps/nm-km) @ 1310 nm, 1550 nm

Loose Buffer Constructions

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz–km) @850nm, 1300nm	Materials		
						Outer Jacket	Inner Jacket	Strength Member
Interbuilding Trunk Cables								
MFPT–Unarmored								
221704		20	Single Mode		0.5/2.8,0.4/18 #	PE	—	FGE/K
221706		20		6		PE	—	FGE/K
221708		20		8		PE	—	FGE/K
221710		20		10		PE	—	FGE/K
221712		20		12		PE	—	FGE/K
221716		20		16		PE	—	FGE/K
221718		20		18		PE	—	FGE/K
221724		20		24		PE	—	FGE/K
221736		20		36		PE	—	FGE/K
221748		20		48		PE	—	FGE/K
221760		20		60		PE	—	FGE/K
221772		20		72		PE	—	FGE/K
227714		21	50/125-FDDI	4	3.0/500,1.0/500	PE	—	FGE/K
227716		21		6		PE	—	FGE/K
227718		21		8		PE	—	FGE/K
227713		21		10		PE	—	FGE/K
227715		21		12		PE	—	FGE/K
227717		21		18		PE	—	FGE/K
227724		21		24		PE	—	FGE/K
227736		21		36		PE	—	FGE/K
227748		21		48		PE	—	FGE/K
227760		21		60		PE	—	FGE/K
227772		21		72		PE	—	FGE/K
225714		22	62.5/125-FDDI	4	3.5/160,1.0/500	PE	—	FGE/K
225716		22		6		PE	—	FGE/K
225718		22		8		PE	—	FGE/K
225713		22		10		PE	—	FGE/K
225715		22		12		PE	—	FGE/K
225717		22		18		PE	—	FGE/K
225724		22		24		PE	—	FGE/K
225736		22		36		PE	—	FGE/K
225748		22		48		PE	—	FGE/K
225760		22		60		PE	—	FGE/K
225772		22		72		PE	—	FGE/K
MFPT–Armored								
221502		20	Single Mode	2	0.5/2.8,0.4/18 #	PE	—	FGE/K
221504		20		4		PE	—	FGE/K
221506		20		6		PE	—	FGE/K
221508		20		8		PE	—	FGE/K
221510		20		10		PE	—	FGE/K
221512		20		12		PE	—	FGE/K
221516		20		16		PE	—	FGE/K
221518		20		18		PE	—	FGE/K
221524		20		24		PE	—	FGE/K
221536		20		36		PE	—	FGE/K
221548		20		48		PE	—	FGE/K
221560		20		60		PE	—	FGE/K
221572		20		72		PE	—	FGE/K
227502		21	50/125-FDDI	2	3.0/500,1.0/500	PE	—	FGE/K
227504		21		4		PE	—	FGE/K
227506		21		6		PE	—	FGE/K
227508		21		8		PE	—	FGE/K
227510		21		10		PE	—	FGE/K
227512		21		12		PE	—	FGE/K
227518		21		18		PE	—	FGE/K
227524		21		24		PE	—	FGE/K
227536		21		36		PE	—	FGE/K
227548		21		48		PE	—	FGE/K
227560		21		60		PE	—	FGE/K
227572		21		72		PE	—	FGE/K

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Loose Buffer Constructions (cont.)

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz–km) @850nm, 1300nm	Materials		
						Outer Jacket	Inner Jacket	Strength Member
MFPT–Armored (cont.)								
225502		22	62.5/125-FDDI	2	3.5/160,1.0/500	PE	—	FGE/K
225504		22		4		PE	—	FGE/K
225506		22		6		PE	—	FGE/K
225508		22		8		PE	—	FGE/K
225510		22		10		PE	—	FGE/K
225512		22		12		PE	—	FGE/K
225518		22		18		PE	—	FGE/K
225524		22		24		PE	—	FGE/K
225536		22		36		PE	—	FGE/K
225548		22		48		PE	—	FGE/K
225560		22		60		PE	—	FGE/K
225572		22		72		PE	—	FGE/K
MFPT–Heavy Duty								
221411		20	Single Mode	1	0.5/2.8,0.4/18 #	PE-	PVC	K
221432		20		2		PE	PVC	K
221402		20		2		PE	PVC	K
221404		20		4		PE	PE	FGE/K
221406		20		6		PE	PE	FGE/K
221408		20		8		PE	PE	FGE/K
221410		20		10		PE	PE	FGE/K
221412		20		12		PE	PE	FGE/K
221416		20		16		PE	PE	FGE/K
221418		20		18		PE	PE	FGE/K
221424		20		24		PE	PE	FGE/K
221436		20		36		PE	PE	FGE/K
221448		20		48		PE	PE	FGE/K
221460		20		60		PE	PE	FGE/K
221472		20		72		PE	PE	FGE/K
227411		21	50/125-FDDI	1	3.0/500,1.0/500	PE	PVC	K
227412		21		2		PE	PVC	K
229657		21		2		PE	PVC	K
227414		21		4		PE	PE	FGE/K
227416		21		6		PE	PE	FGE/K
227418		21		8		PE	PE	FGE/K
227413		21		10		PE	PE	FGE/K
227415		21		12		PE	PE	FGE/K
227417		21		18		PE	PE	FGE/K
227424		21		24		PE	PE	FGE/K
227436		21		36		PE	PE	FGE/K
227448		21		48		PE	PE	FGE/K
227460		21		60		PE	PE	FGE/K
227472		21		72		PE	PE	FGE/K
225411		22	62.5/125-FDDI	1	3.5/160,1.0/500	PE	PVC	K
225412		22		2		PE	PVC	K
225432		22		2		PE	PVC	K
225414		22		4		PE	PE	FGE/K
225416		22		6		PE	PE	FGE/K
225418		22		8		PE	PE	FGE/K
225413		22		10		PE	PE	FGE/K
225415		22		12		PE	PE	FGE/K
225417		22		18		PE	PE	FGE/K
225424		22		24		PE	PE	FGE/K
225436		22		36		PE	PE	FGE/K
225448		22		48		PE	PE	FGE/K
225460		22		60		PE	PE	FGE/K
225472		22		72		PE	PE	FGE/K

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FCP = Fluorocopolymer
FGE = Fiberglass Epoxy Rod
K = Kevlar

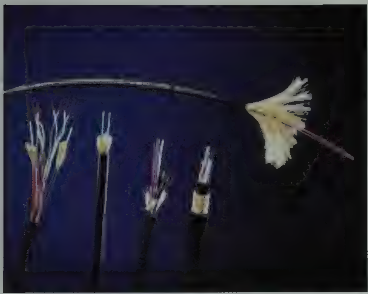
FA = Flamarrest™
MFPT = Multifiber Per Tube
OFN = Vertical Tray Listed
OFNR = Riser Listed
OFNP = Plenum Listed
# = Attenuation/dispersion (dB/km / ps/nm-km) @ 1310 nm, 1550 nm

Loose Buffer Constructions (cont.)

Trade No.	NEC Code	Page No.	Fiber Size (Core/Clad)	Fiber Count	Attn/Bandwidth (dB/km / MHz–km) @850nm, 1300nm	Materials		
						Outer Jacket	Inner Jacket	Strength Member
Bundled–Unarmored								
551704		24	Single Mode	4	0.4/2.8,0.3/18 #	PE	—	FGE
551706		24		6		PE	—	FGE
551708		24		8		PE	—	FGE
551710		24		10		PE	—	FGE
551712		24		12		PE	—	FGE
551716		24		16		PE	—	FGE
551718		24		18		PE	—	FGE
551724		24		24		PE	—	FGE
551736		24		36		PE	—	FGE
551748		24		48		PE	—	FGE
551760		24		60		PE	—	FGE
551772		24		72		PE	—	FGE
Bundled–Armored								
551504		24	Single Mode	4	0.4/2.8,0.3/18 #	PE	—	STEEL
551506		24		6		PE	—	STEEL
551508		24		8		PE	—	STEEL
551510		24		10		PE	—	STEEL
551512		24		12		PE	—	STEEL
551516		24		16		PE	—	STEEL
551518		24		18		PE	—	STEEL
551524		24		24		PE	—	STEEL
551536		24		36		PE	—	STEEL
551548		24		48		PE	—	STEEL
551560		24		60		PE	—	STEEL
551572		24		72		PE	—	STEEL
General Purpose								
227201	OFN	26	50/125-FDDI	1	3.0/500,1.0/500	PVC	—	K
227202	OFN	26		2		PVC	—	K
225201	OFN	26	62.5/125-FDDI	1	3.5/160,1.0/500	PVC	—	K
225202	OFN	26		2		PVC	—	K
226021	OFN	26	100/140	1	5.0/100,4.0/200	PVC	—	K
226022	OFN	26		2		PVC	—	K

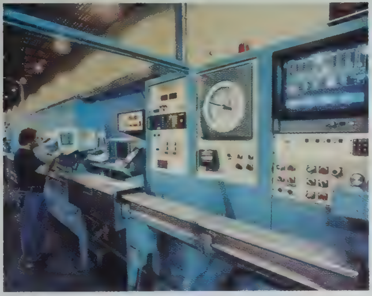
PU = Polyurethane
PE = Polyethylene
PVC = Polyvinylchloride
FCP = Fluorocopolymer
FGE = Fiberglass Epoxy Rod
K = Kevlar

FA = Flamarrest®
MFPT = Multifiber Per Tube
OFN = Vertical Tray Listed
OFNR = Riser Listed
OFNP = Plenum Listed
# = Attenuation/dispersion (dB/km / ps/nm-km) @ 1310 nm, 1550 nm



Belden Special Fiber Optic Cable Designs for Unique Applications.

Belden is committed to engineering systems that ensure consistent product performance.



Belden is leading the way in developing new cost effective processes and materials.

Every Belden product is built on applied research and technical experience.

Make the Belden Customer Service Advantage Work For You

At Belden, our number one priority is customer service.

That's why we welcome the opportunity to help you design a custom-made fiber optic cable that's created for your special applications. Our resources are second-to-none. The best resources in fiber optics and state-of-the-art technology are housed in our Belden Engineering Center. And each of these is readily accessible when you call Belden Product Engineering at **1-317-983-5200.**

We also welcome the opportunity to meet your private label marketing needs—with both standard and custom-designed products. Call Belden Fiber Optics Marketing at **1-317-983-5200** for more information.

Only Belden offers this outstanding combination of technology and resources to hundreds of customers seeking the very best in fiber optics. We recognize this as a commitment to our customers. You'll recognize it as the Belden Customer Service Advantage.

Belden is Committed to Advanced Technology

The most progressive and innovative cable development and OEM customer service facility in the world belongs to Belden.

And thats what sets us apart from the competition.

Our 70,000 square-foot facility is filled with the finest minds in fiber optics. Hundreds of engineers and technicians perform the research and development necessary to meet the world's needs for fiber optics. And while these facts may sound impressive, Belden is committed to an even greater growth in fiber optics. One that meets tomorrow's needs as well. One that dedicates even more technology, more personnel, and more resources to a future wtih fiber optics.

Belden Documents SPC Histories on Production Runs

Here's another Belden Advantage that works for you! If you ask us, we will prepare a data-based history of the fiber optic cable production run on your OEM order. This data base or Statistical Process Control (SPC) will be prepared by sample or complete lots, depending on your needs. It's our way of helping you acheive maximum quality control, both on your first and future orders with Belden.

Belden—An Active Force in Industry Standardization

While many systems currently utilize fiber optic interfaces, standards in the industry are still being formed. Belden maintains an active role in the guidance of numerous industry bodies. Belden sits on standing committees of NEMA, IEEE, and EIA for example, and maintains formal and ongoing relations with standard enforcing organizations like U.L. and C.S.A. Current developments which Belden cables fully support include:

- FDDI (Fiber Distributed Data Interface) Physical Media Document adopted by ANSI (American National Standards Institute) for 100Mb LANs.
- IEEE (Institute of Electrical & Electronic Engineering) 802 Committees, specifying fiber optic cable standards for network architectures such as Ethernet, Token Ring, Token Bus, and MAP (Manufacturing Automation Protocol).
- Electronics Industry Association (EIA) TR41.8 endorsement of 62.5/125 micron fiber for building wire applications.
- Independent testing and certification of IBM specified LAN cables by ETL.

Fiber Optic Cables Cut to Length

Belden® fiber optic cable is provided in standard lengths (put-ups) of 2 km (6560 ft.). However, put-ups may be ordered in any length desired. Lengths longer than 2 km are available upon request. This service is offered by Belden at no extra charge.

Replacement Guarantee

If it is determined that your Belden cable product is factory defective after it has been properly installed, Belden will remove the cable and replace it with a new one free of charge. For full details, please refer to the Terms and Conditions of Sale.

Fiber Optics Training Programs

Belden supports its product offering with customized training programs. For information about Belden Fiber Optics Training Programs, contact Belden Fiber Optics Marketing at **1-317-983-5200**.

Sales/Application Services

Serving You at Home and Abroad

With sales offices and representatives throughout North America, Europe, United Kingdom, Far East, Middle East, Africa, and the Pacific Rim, Belden spans the globe to serve customers wherever they do business. Belden's extensive network of sales professionals stand ready to aid you with expert advice and service.

If you are interested in learning more about Belden firsthand, we cordially invite you to visit our world headquarters and facilities in Richmond, Indiana for a personal tour. For arrangements, contact the Regional Sales Office nearest you at **1-800-BELDEN-1**.

Belden Sales Offices

Each of our seven regional sales offices (listed on the back cover of this catalog) include highly-skilled Network Specialists and Sales Representatives with the product expertise to help you select and implement the right cabling solution. Call **1-800-BELDEN-1** to reach the sales office nearest you.

Authorized Belden Systems Integrators

For systems design, hardware, cabling, and installation, our network of Authorized Systems Integrators across the nation is uniquely qualified to offer Belden products as integral components in your complete turnkey system. For more information and name of the Authorized Belden Systems Integrator nearest you, call **1-800-BELDEN-1**.

Belden Distribution Network

Your local Authorized Belden Distributor is equipped to respond quickly to your needs, with the right fiber optic cable in stock. The Belden Distributor Network is one of the most comprehensive of its kind, working closely with customers, in touch and ready to respond. To reach your local Belden Distributor, call the Belden Regional Sales Office nearest you at **1-800-BELDEN-1**.

Quality at Belden: The Evolution of an Absolute

At Belden, quality means conformance to requirements. It is the critical component in virtually every business function or process we perform. From design to manufacturing to customer service, quality improvement drives everything we do.

In the past, quality has primarily been associated with defect-free manufacturing, but at Belden, our definition of quality has grown into something more comprehensive. We equate quality with an individual commitment to doing the job right the first time it is done. We believe responsibility for quality applies to every employee in the Belden organization, in each and every facet. While job functions may vary, each employee has specific requirements which can be defined. Conformance to those requirements is essential, precisely because it impacts the ultimate cost of quality.

Where fiber optic technologies are concerned, Belden, as always, strives to maintain a zero-defect standard of performance. The Belden quality philosophy is helping to produce a fiber optic product that is second to none in customer satisfaction.

Our emphasis is one of raising quality consciousness, company-wide. To facilitate and articulate awareness of quality, Belden has established a long-term Quality Improvement Process that incorporates the ideas of several management experts.

The Absolutes of Quality

The Belden Quality Improvement Process is based on the teachings of Philip Crosby, who argues that goods and services must converge to satisfy customer needs. This implies that subjective measures of service will disappear in favor of objective, requirement-based assessments.

From Crosby, we have adopted the following principles or "absolutes" of quality management to guide our work:

1) Quality must be defined as conformance to requirements, not goodness.
2) The system for causing quality is prevention, not appraisal.
3) The performance standard must always be zero-defects, never "that's close enough."
4) The measure of quality is the price of non-conformance, not indices.

Unlike some quality programs that are short-term in duration, Belden regards its quality commitment as a perpetual process. This means structuring our thoughts and actions towards achieving and sustaining a hassle-free environment for Belden customers. It also means addressing the rules and regulations we create—with good intention—that can become obstacles to doing good business.

Every Belden employee is oriented towards achieving a hassle-free environment through interdisciplinary cooperation. Our objectives are to think continuously of meeting our customers' unique needs, while sharing information that will assist in this process. The result is an individual commitment to defining and meeting every customer's requirements *100% of the time.* Not 90%. Not 95%. 100%.

That's the spirit permeating Belden today—our products and services are an absolute manifestation of it.

At Belden, stringent testing helps achieve optimum product performance.

Quality means meeting customer requirements 100% of the time.

Statistical Process Control (SPC) is an integral part of Belden manufacturing.

Color Code Chart for Fiber Optic Cables

Fiber No.	Color	Fiber No.	Color Combination
1	Blue	13	Blue/Black Stripe
2	Orange	14	Orange/Black Stripe
3	Green	15	Green/Black Stripe
4	Brown	16	Brown/Black Stripe
5	Slate	17	Slate/Black Stripe
6	White	18	White/Black Stripe
7	Red	19	Red/Black Stripe
8	Black	20	Natural/Black Stripe
9	Yellow	21	Yellow/Black Stripe
10	Violet	22	Violet/Black Stripe
11	Aqua	23	Aqua/Black Stripe
12	Rose	24	Rose/Black Stripe

Metric/Imperial Units Conversion

To Convert From:	To:	Multiply By:
To Convert To:	**From:**	**Divide By:**
microns	mils	.03937
mm	in.	.03937
cm	in.	.39370
m	ft.	3.2808
km	ft.	3280.8
km	mi	.62137
kg	lbs	2.2046
kg/km	lbs/1000 ft.	.67197
N	lbs	.2248
N-m	ft.–lbs	.73757
N/cm	lbs/in.	.5710
kPa	PSI	.14511

°F = 9/5 (°C) + 32 | °C = 5/9 (°F–32)

Outside Jacket Color Code Chart for Fiber Optic Cables

Cable Family	Jacket Material	Jacket Color
BitLite®	PVC FA	Light Gray Natural
LANLite™	PVC FCP FA	Orange White Natural
Breakout	PVC FCP	Light Blue Black
SuperLite™	PVC FCP	Black Black
Interbuilding Trunk	PE	Black
General Purpose	PVC	Light Blue
DECconnect	PVC 2–fiber PVC Light Duty PVC Heavy Duty FCP Light Duty FCP Heavy Duty	DEC Gray Orange Orange Orange Orange

Interbuilding Trunk Multifiber per Tube Configurations

Fiber Count	Buffer Tube Configuration
1–6	One fiber per tube
8	2 tubes of 4 fibers, 4 filler tubes
10	One tube of 6, one tube of 4, 4 filler tubes
12	2 tubes of 6, 4 filler tubes
16	2 tubes of 6, one tube of 4, 3 filler tubes
18–72	6 fibers per tube

Introduction

This section covers three basic areas of fiber optics technology.

- Basic guide to fiber optics
- Fiber optic system design
- Fiber optic cable installation

Basic Guide to Fiber Optics

The Advantages of Fiber

Fiber optics communication offers several advantages over metallic systems.

The transmitted signals are not distorted by any form of outside electronic, magnetic, or radio frequency interference. Therefore, optical cables are completely immune to lightning or high voltage interference.

Furthermore, optical fibers will emit no radiation, which ideally suits them for today's tougher standards in computer applications. Because optical signals do not require grounding connections, the transmitter and receiver are electrically isolated and free from ground loop problems.

With no chance of terminal-to-terminal ground potential shifts, plus safety from sparking and shock, fiber optics is increasingly the choice for many processing applications where safe operation in hazardous or flammable environments is a requirement.

Digital computing, telephone, and video broadcast systems require new avenues for improved transmission. The high signal bandwidth of optical fibers means increased channel capacity. Also, longer cable runs require fewer repeaters, because fiber optic cables have extremely low attenuation rates. This ideally suits them for broadcast and telecommunications use.

Compared to conventional coaxial cables with the same signal carrying ability, the smaller diameter and lighter weight of fiber optic cables means relatively easier installation, especially in crowded duct areas. A single conductor fiber optic cable weighs about 9 lbs. per 1,000 ft. A comparable coaxial cable weighs 80 lbs. per 1,000 ft.—about nine times more.

All Dielectric • Low Signal Radiation • Secure Transmission • RFI and EMI Immunity • Lightning Immunity • High Voltage Installations
Small Size • Less Duct Space • Fewer Additional Ducts Installed
Low Attenuation • Greater Distance/Fewer Repeaters • Less Installation and Maintenance
Optical Signals • No Ground Loops • No Spark Hazard • Operation in Flammable Areas
High Bandwidth • Future Signal Capacity Expansion

Table 1—Features of Fiber Optic Systems.

Electronic "bugging" depends on electromagnetic monitoring. Fiber optic systems are immune to this technique. They have to be physically tapped to extract data, which decreases signal levels and increases error rates—both of which are readily detected. Table 1 summarizes the many features of fiber optic systems.

Basic Elements of Optical Fiber

Fiber Structure

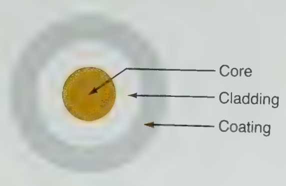


Figure 1—A cross-section of optical fiber.

Core

This is the light transmission area of the fiber, either glass or plastic. The larger the core, the more light that will be transmitted into the fiber (see Figure 1).

Cladding

The function of the cladding is to provide a lower refractive index at the core interface in order to cause reflection within the core so that lightwaves are transmitted through the fiber.

Coating

Coatings are usually multi-layers of plastic applied to preserve fiber strength, absorb shock and provide extra fiber protection. These buffer coatings are available from 250 microns to 900 microns.

Fiber size

The size of an optical fiber is commonly referred to by the outer diameter of its core, cladding and coating. Example: 50/125/250 indicates a fiber with a core of 50 microns, cladding of 125 microns, and a coating of 250 microns. The coating is always removed when joining or connecting fibers.

A micron (μm) is equal to one-millionth of a meter. 25 microns are equal to $^{1}/_{1000}$ of an inch. A sheet of paper is approximately 25 microns thick.

Fiber Types

Fiber can be identified by the type of paths that the light rays, or modes, travel within the fiber core. There are two basic types of fiber: multimode and single mode.

Multimode fiber cores may be either step index or graded index. Step index multimode fiber derives its name from the sharp steplike difference in the refractive index of the core and cladding.

In the more common graded index multimode fiber the light rays are also guided down the fiber in multiple pathways. But unlike step index fiber, a graded index core contains many layers of glass, each with a lower index of refraction as you go outward from the axis.

The effect of this grading is that light rays are speeded up in the outer layers, to match those rays going the shorter pathway directly down the axis.

The result is that a graded index fiber equalizes the propagation times of the various modes so that data can be sent over a much longer distance and at higher rates before light pulses start to overlap and become less distinguishable at the receiver end.

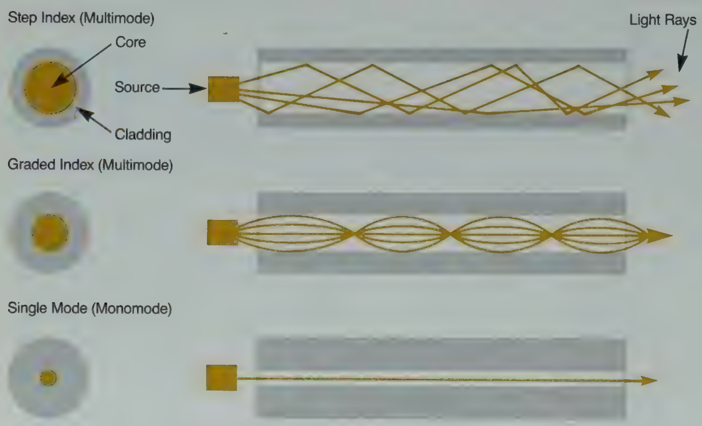


Figure 2—A graphic representation of how light rays travel in three fiber types.

Graded index fibers are commercially available with core diameters of 50, 62.5, 85 and 100 microns.

The single mode fiber allows only a single light ray or mode to be transmitted down the core. This virtually eliminates any distortion due to the light pulses overlapping.

The core of a single mode fiber is extremely small, approximately five to ten microns.

The single mode fiber has a higher capacity and capability than either of the two multimode types. For example, single mode fiber can handle a 40 channel video system for 15 miles without a repeater.

System Design Considerations

When selecting components for a fiber optic system, there are two optical fiber factors that affect transmission performance: bandwidth and attenuation.

Bandwidth

Bandwidth is the measure of the data carrying capacity of the fiber. The greater the bandwidth, the greater the information capacity.

Bandwidth is expressed in a frequency-distance form (MHz-km). Example: A 200MHz-km fiber can move 200 MHz of data up to one kilometer or 100MHz of data as far as two kilometers.

Attenuation

In addition to physical changes to the light pulse which result from frequency or bandwidth limitations, there are also reductions in the level of optical power as the light pulse travels to and through the fiber.

This optical power loss, or attenuation, is expressed in dB/km (decibels per kilometer) at a specified wavelength.

Intrinsic Optical Fiber Loss

Light is an electromagnetic wave of vibrating nature. Short wavelengths are in the ultraviolet spectrum.

Microwaves, radar, television and radio operate in the longest wavelength areas. In between the ultraviolet and the microwave spectrums, we have fiber optic wavelengths, which are in the infrared spectrum.

Just as the speed of light slows when traveling in transparent materials, each infrared wavelength is transmitted differently within the fiber. Therefore, attenuation, or optical power loss, must be measured in specific wavelengths for each fiber type. (See Figure 3).

Wavelengths are measured in nanometers (nm)—billionths of meters—which represent the distance between two cycles of the same wave.

Losses of optical power at the different wavelengths occur in the fiber due to absorption, reflection and scattering. These occur over distance depending on the specific fiber, its size, purity and refraction indexes.

The amount of optical power loss due to absorption and scattering of optical radiation at a specified wavelength is expressed as an attenuation rate in decibels of optical power per kilometer (dB/km).

Fibers are optimized for operation at certain wavelengths. For example, less than 1dB/km loss is attainable in 50/125 µm multimode fiber operating at 1300 nm, and less than 3dB/km (50% loss) is attainable for the same fiber operating at 850 nm.

These two wavelength regions, 850 or 1300 nms, are the areas most often specified for fiber optic transmission today. These wavelengths are commercially useable with today's transmitters and receivers. Optical fibers have also been optimized at the 1550 nm region for single mode transmission systems.

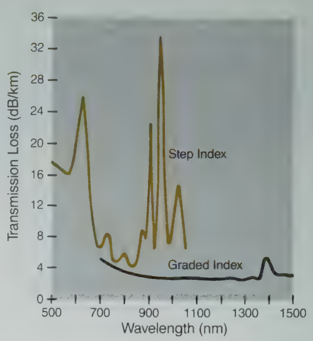


Figure 3—Transmission loss, or attenuation varies with wavelength.

Microbending loss

Without protection, an optical fiber is subject to losses of optical power caused by microbending.

Microbends are minute fiber deviations caused by lateral forces which cause optical power loss from the core.

Different types of protection for the fiber are available to minimize microbending.

Step index fibers are relatively more resistant to microbending losses than graded index.

Cabling Design Considerations

Considerations of tensile strength, ruggedness, durability, flexibility, size, resistance to the environment, flammability, temperature range and appearance are important in constructing optical fiber cable.

First Level of Fiber Protection

The optical fiber is a very small waveguide. In an environment free from stress or external forces, this waveguide will transmit the light launched into it with minimal loss, or attenuation.

To isolate the fiber from these external forces, two first level protections of fiber have been developed: loose buffer and tight buffer (see Figure 4).

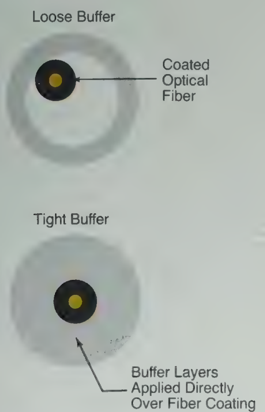


Figure 4—Examples of loose and tight buffer constructions

In the loose buffer construction, the fiber is contained in a plastic tube that has an inner diameter considerably larger than the fiber itself. The interior of the plastic tube is usually filled with a gel material.

The loose tube isolates the fiber from the exterior mechanical forces acting on a cable. For multifiber cables, a number of these tubes, each containing single or multiple fibers, are combined with strength members to keep the fibers free of stress, and to minimize elongation and contraction.

By varying the amount of fiber inside the tube during the cabling process, the degree of shrinkage due to temperature variation can be controlled, and therefore the degree of attenuation over a temperature range is minimized.

The other fiber protection technique, tight buffer, uses a direct extrusion of plastic over the basic fiber coating.

Tight buffer constructions are able to withstand much greater crush and impact forces without fiber breakage.

The tight buffer design, however, results in lower isolation for the fiber from the stresses of temperature variations. While relatively more flexible than loose buffer, if the tight buffer is deployed with sharp bends or twists, optical losses are likely to exceed nominal specifications due to microbending.

A refined form of tight buffer construction is breakout cable. In breakout cable, a tightly buffered fiber is surrounded by Kevlar® and a jacket, typically PVC. These single-fiber subunit elements are then covered by a common sheath to form the breakout cable. This "cable within a cable" offers the advantage of direct, simplified connector attachment and installation.

Each construction has inherent advantages. The loose buffer tube offers lower cable attenuation from microbending in any given fiber, plus a high level of isolation from external forces. Under continuous mechanical stress, the loose tube permits more stable transmission characteristics.

The tight buffer construction permits smaller, lighter-weight designs for similar fiber configuration, and generally yields a more flexible, crush-resistant cable.

The advantages of both tight and loose buffers are outlined in Table 2.

Cable Parameter	Cable Structure		
	Loose Tube	Tight Buffer	Breakout
Bend Radius	Larger	Smaller	Larger
Diameter	Larger	Smaller	Larger
Tensile Strength, Installation	Higher	Lower	Higher
Impact Resistance	Lower	Higher	Higher
Crush Resistance	Lower	Higher	Higher
Attenuation Change At Low Temperatures	Lower	Higher	Higher

Table 2—Loose and Tight Buffer Tradeoffs

Physical Choices

Once a tight or loose buffer construction is selected, the system designer has made some decisions regarding the tradeoffs between microbending loss and flexibility in obtaining his optical operation goals.

For installation of a cable, mechanical properties such as tensile strength, impact resistance, flexing, and bending are important. Environmental requirements concern the resistance to moisture, chemicals, and other types of atmospheric or in-ground conditions.

Mechanical Protection

Normal cable loads sustained during installation may ultimately place the fiber in a state of tensile stress.

The levels of stress may cause microbending losses which result in an attenuation increase and possible fatigue effects.

To transfer these stress loads in short term installation and long-term application, various internal strength members are added to the optical cable structure.

Such strength members provide the tensile load properties similar to electronic cables, and keep the fibers free from stress by minimizing elongation and contraction. In some cases, they also act as temperature stabilization elements.

Table 5 indicates the relative performance considerations for each of several common strength members.

Optical fiber stretches very little before breaking, so the strength members must have low elongation at the expected tensile loads.

STRENGTH MEMBERS				
	Load to Break Lbs.	Diameter in.	Elongation Break %	Weight Lbs. K Ft.
Fiberglass Epoxy Rod	480	.045	3.5	1.4
Steel	480	.062	0.7	7.5
Kevlar	944	.093	2.4	1.8

Table 5—Strength Member Comparison

Impact resistance, flexing and bending are other mechanical factors affecting choice of strength members.

• DuPont trademark

Strength members which are typically used in fiber optic cable include Kevlar* fiberglass epoxy rods, and steel wire. Pound for pound, Kevlar is five times stronger than steel. It and fiberglass epoxy rods are often the choice when all-dielectric construction is required.

Steel is sometimes chosen when extreme cold temperature performance is required, since it can offer better temperature stability.

For outdoor applications, Belden fiber optic cables are configured with a single jacket, two jackets or with Belclad® armor for aerial, underground duct and direct burial installation.

Belden fiber optic cables for indoor applications meet the requirements of the plenum, riser and vertical tray cable specifications of the National Electrical Code** (NEC/CSA). Belden also offers cables meeting today's specifications for Halogen-free environments.

Fiber Count

Specifying the number of fibers used in the cable plant requires the designer to carefully consider the evolution of future networking demands. Depending on the number and type of applications in the network and level of redundancy needed, fiber count can range from 2 to more than 100 in the backbone or to each wiring closet. The following chart summarizes the fiber requirements for various applications.

Application	One Fiber	Two Fibers	Four Fibers
FDDI			■
Ethernet		■	
Token Ring		■	
Channel Extension		■	
CCTV Security	■		
Interactive Video		■	
Voice		■	
Telemetry	■	■	

Currently, due to the expense of multiplexing equipment, separate, dedicated fibers are typically utilized for each application. So, for example, if two buildings were to be networked with an FDDI backbone, four fibers would be required in the cable connecting the buildings—two to transmit, two to receive. Further, it is recommended that at least two times the number of fibers needed are actually placed in the backbone to accommodate expansion requirements.

For purposes of example, assume 3 applications to each floor.

1. FDDI data (4 fibers)
2. Interactive video (2 fibers)
3. CCTV Security (1 fiber)

These applications would indicate a need for 7 fibers to each wiring closet. It is recommended that 2 times the number of fibers required are actually run to each wiring closet to allow future network expansion.

Although some systems clearly indicate the number of fibers needed, there are usually no hard and fast rules. Installing the required number of fibers plus others for backup and for the future yields the most flexible, expandable cable plant to service networking requirements into the future.

* DuPont trademark.

** Tradename of the National Fire Protection Agency, Quincy, MA.

Fiber Optic System Design

The Fiber Optic Link

The simple schematic diagram is shown in Figure 5 consists of an optical transmitter and receiver connected by a length of optical cable in a point-to-point link.

The optical transmitter converts electronic signal voltage into optical power which is launched into the fiber by a light emitting diode (LED), laser diode (LD) or laser.

At the photodetector point, either a positive-intrinsic-negative (PIN) or avalanche photodiode (APD) capture the lightwave pulses for conversion back into electrical current.

It is the system designer's job to determine the most cost and signal efficient means to convey this optical power, knowing the tradeoffs and limits of various components. He must also design the physical layout of the system.

The first of these concerns, signal quality, involves such factors as signal-to-noise ratio (SNR) in analog systems, and bit-error-rate (BER) in digital systems. When designing a system "from scratch" the designer must determine the required SNR or acceptable BER necessary to transfer the data. The next step is to determine the minimum optical power necessary at the receiver end. This can be obtained from component manufacturer's published data.

Losses and Limitations

Link design consists basically of two functions: (1) calculating optical power losses occurring between the light source and the photodetector, and (2) determining bandwidth limitations on data carrying abilities imposed by the transmitter, fiber, and receiver.

Reductions in optical power loss, or attenuation, as the light pulse travels through the fiber are expressed in dB/km (decibels per kilometer).

The decibel is a logarithmic expression of the ratio for the power entering a component and the power leaving it.

$$\text{dB} = 10 \log_{10} \frac{\text{Power out}}{\text{Power in}}$$

A 3dB loss means that half the power is lost. For example, starting with 500μW, you would now have 250μW. A 10dB loss means that $^1/_{10}$ of the power arrives at the receiver, a 90% loss.

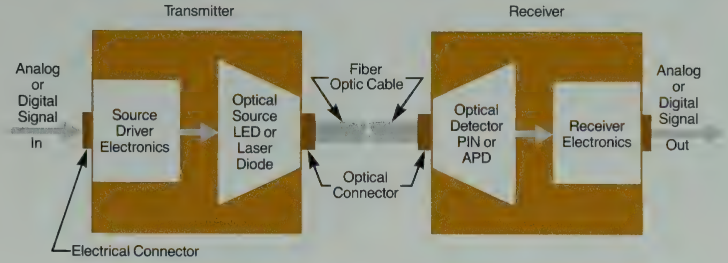
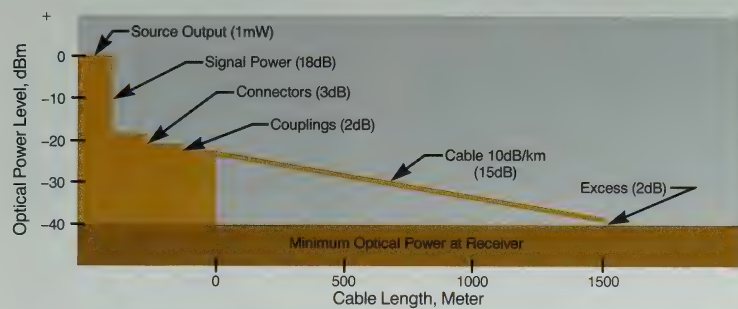


Figure 5—Simple Fiber Optic Link



		Actual Power	Optical Power Level
Minimum optical power required by the receiver		0.1μW	–40 dBm
Source output optical power		1mW	0 dBm
Total operating budget (optical power)			40 dB
SNR voltage ratio required in the receiver is 36 dB. The equivalent optical power ratio is*			18 dB
Remaining optical power for link			22 dB
Link optical power losses:			
Cable	15 dB		
Connectors	3 dB		
Couplings	2 dB		
Total	20 dB		
Excess budget			**2 dB**

*The optical power ratio is related to the signal voltage ratio by a factor of two because dB = 10 log P_1/P_2 = 10 log I_1^2R/I_2^2R. Since V = IR then dB = 20 log V_1/V_2.

Figure 6—Typical Optical Link Power Budget

Fiber optic links can operate with as little as $^1/_{1000}$ of the input power being received at the other end (a 30dB loss).

If the source emits sufficient power and the receiver is sensitive enough, the system can operate with high losses. How much loss can be tolerated will be determined by the stated minimum requirements of the receiver selected.

Transmission Power Loss

The prime causes of optical attenuation in fiber systems are:

- coupling loss
- optical fiber loss
- connector loss
- splice loss

The sum of the losses of each individual component between transmitter and receiver comprise the Optical Link Power Budget shown in Figure 6.

The designer must consider these losses and select a transmitter and receiver combination that will deliver enough power to faithfully reproduce the signal.

However, these losses are not exact, and manufacturers typically state ranges, or "best" and "worst" case situations in order to account for product variations. Also some allowance may be required for such things as temperature variations.

Some safety margins should also be made for future repairs or splices to the system, and age degradation of the source emitter. For example, a 3 to 6dB margin for repairs and aging of the emitter is commonly employed.

Coupling Loss

The amount of optical power coupled into the fiber is dependent on the physical nature of the fiber used, and the source emitter.

Obviously, the larger the core diameter of the fiber, the more potential for accepting light. However, larger core fibers suffer bandwidth limitations that may outweigh coupling efficiency.

A change in core diameter from 50mm to 100μm (microns) represents an increase of four times in the amount of light coupled to the fiber.

Besides core size, the other measure of a fiber's ability to collect optical power is called numerical aperture (NA). This is a mathematical measure of the fiber core's ability to accept lightwaves from various angles and transmit them down to the core.

A large difference between the refractive indices of the core and cladding means a larger NA. For equal core sizes, a fiber with a larger NA will accept more lightwaves. A power increase by about a factor of two is achieved by going from an NA of 0.20 to one of 0.29.

We've combined the effects of core size and NA into an Optical Collection Factor which can be considered a measure of the fiber's efficiency for optical radiation (see Table 6).

Fiber Core Dia. Microns	Numerical Aperture	Collection Factor	
		Relative*	dB Ratio
200	0.27	3.5	+5.4
100	0 29	1.0	+0.0
85	0.26	0.58	-2.36
62.5	0.275	0.35	-4.54
50	0.20	0.12	-9.25

*Values normalized to short length of 100 micron core fiber.

Table 6—Optical Collection Factor.

Component Selection

Source Emitters

Optical emitters couple light into a fiber according to NA and core size. Using a light source not matched to a particular fiber's NA and core size will cause less than optimum light coupling for the system.

LEDs are relatively inexpensive, reliable and easy-to-use because their electronic circuitry is less complex than that required for a laser.

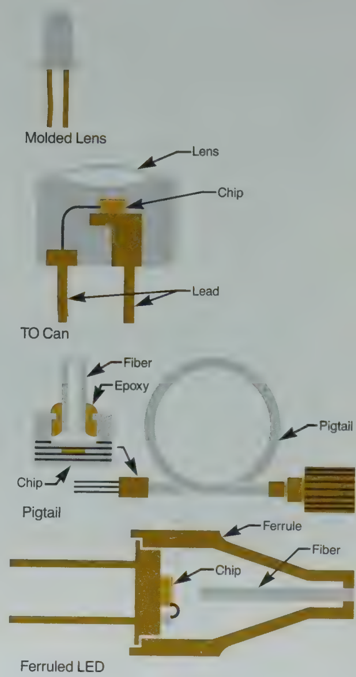


Figure 7—LED Packaging Styles.

Semiconductor lasers and LEDs are both direct transducers from electrical to optical radiation. LEDs couple less power into the fiber because they emit the optical radiation over a broader angle area. The laser is a much more complicated structure due to the requirement for a small dual-face cavity. Also its output is temperature dependent and the lifetime is less than the LED.

Several different LED packaging styles are commercially available, as seen in Figure 7.

The LED or laser diode can be packaged so that the fiber cable plugs directly into the device package. An alternative is fastening the fiber directly to the chip and leaving the opposite end available for a connector.

Matched transmitter and receiver units, plus a wide variety of other fiber optic components ranging from discrete elements like LEDs, laser diodes, and detectors to complete rack-mounted modules are all readily available.

Detectors

Lightwave receivers use photodetectors, where the photons of light generate photoelectrons. A minimum average number of photons in each pulse is necessary to achieve a given error probability (21 photons for 10^{-9} error probability). Considerable amplification is necessary. For an avalanche-photodiode (APD) initial amplification is internal. For positive-intrinsic-negative detectors (PIN) this amplification is by external electronic amplifiers.

Optical Fiber Loss

We've already considered core size and numerical aperture as measures of fiber's ability to accept the optical power. Now let's consider what happens to the optical signal once it's launched.

In coaxial cable, the higher the frequency, the more signal strength decreases with distance and this is referred to as attenuation. Fiber frequency is constant until it reaches its bandwidth limit. Thus optical loss is proportional to distance.

This attenuation within the fiber is caused by absorption and scattering of lightwaves due to chemical impurities and molecular structure. These fiber properties absorb or scatter the optical radiation so that it escapes the core and is lost.

Attenuation within a fiber is specified by the manufacturer at certain wavelengths: for example 5dB/km at 850 nanometers. This is done because fiber loss varies with wavelength, as seen in Figure 8.

These wavelengths are measured in nanometers (nm)—billionths of a meter—which represent the distance between two cycles of the same wave. Wavelength is a descriptive property of electromagnetic radiation. Light and infrared radiation are a portion of the total electromagnetic spectrum.

Microwaves, radar, television and radio operate in the longest wavelength areas. In between the ultraviolet and the microwave spectrums, we have fiber optic wavelengths, which are in the infrared spectrum.

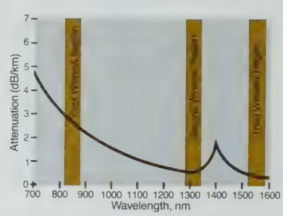


Figure 8—Transmission optical power loss, or attenuation, must be measured in specific wavelengths for each fiber type.

Fiber Selection

Fibers are therefore optimized for operation at certain wavelengths. For example, less than 1 dB/km loss is attainable in 50/125 μm multimode fiber operating at 1300 nm, and less than 3dB/km (50% loss) is attainable for the same fiber operating at 850 nm. The 50/125 nomenclature indicates both the outside diameter of the core (50 microns) and the cladding (125 microns).

The favorable transmission regions within the optical spectrum for a fiber are referred to as "windows". The 800 to 900 nanometer region is the first window, 1100 to 1300 nanometers is the second window, and the third window occurs at about 1550 nanometers. In these spectral windows fibers have very low attenuation. The lowest losses occur in the infrared region around 1300 nm and again around 1550 nm.

Great improvements have been made in all fiber types so that premium fibers exhibit losses of less than 0.5dB/km at wavelengths of 1300 and 1550 nm. However, source emitters and detectors for these regions are currently more expensive.

If the fiber is to perform well, the source chosen should provide optical radiation at the specified wavelength, and the detector should be sensitive to the same wavelength.

In coaxial and other metallic cables, very high frequency signals tend to be attenuated rapidly with distance. As a result, amplifiers and equalizers are required at periodic intervals to build up signals to usable levels.

However, each time an analog amplifier is added, noise is introduced to the metallic system and the overall system signal-to-noise ratio degrades.

With optical communications, all of the light energy is at approximately the same frequency or wavelength. As a result, the attenuation of a specific wavelength is dependent only on distance. See Figure 9 for a comparison of attenuation differences between coaxial and fiber optic cable. The requirement for repeaters is, therefore, minimized and the need for equalizers is eliminated in fiber systems.

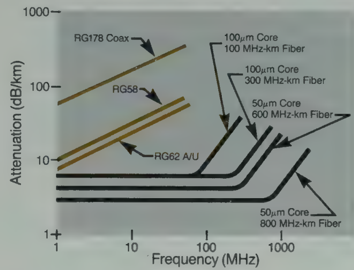


Figure 9—Performance of typical coaxial, and optical cables.

Connector Loss

Connector loss is a function of the physical alignment of one fiber core to another fiber core.

Scratches and dirt can also contaminate connector surfaces and severely reduce system performance, but most often the connector loss is due to misalignment or end separation.

Connectors and connector attachment are covered in the installation portion of this catalog section.

Bandwidth

Up to this point, we've covered loss of optical signal power both within the fiber and within the system.

Now let's examine the other major determinant of fiber optic signal performance: bandwidth.

Because of their large comparative bandwidths, fibers can carry large amounts of information. A single graded index fiber can easily carry 500 million bits/second (Mb/s) of information. However, bandwidth capacity limits exist for all types of fibers and depend on the fiber and type of emitter employed.

To accurately reproduce data, light pulses must be kept separate and distinct with correct shape and spacing during transmission. Yet, the rays comprising each pulse travel in many different paths within a multimode fiber. For step index fibers, for example, modes traveling at different angles as they zigzag down the fiber arrive at the receiver end at different times.

This arrival time variance results in distorted and overlapping pulses at the receiver end as seen in Figure 10. This "modal dispersion," or spreading of the light pulse, limits the frequency that can be transmitted, because the detector cannot tell where one pulse ends and the next begins.

The time difference between the fastest and the slowest mode of light entering the fiber at the same time and traveling a kilometer may only be 1 to 3 nanoseconds, yet this modal dispersion causes major limitations on the system's operating speeds over long distances. Doubling the distance, doubles the dispersion effect.

Just as optical power loss reduces signal performance, a system can be bandwidth limited when the shape of the light pulse is distorted beyond specified limits.

Modal dispersion is often expressed in nanoseconds per kilometer, e.g. 30ns/km. The same effect may also be expressed as a frequency, such as 200 MHz-km. This indicates that the fiber or system will operate efficiently up to 200 MHz before dispersion adversely affects signal performance over a one kilometer length. The same system could transmit a 100 MHz signal as far as two kilometers.

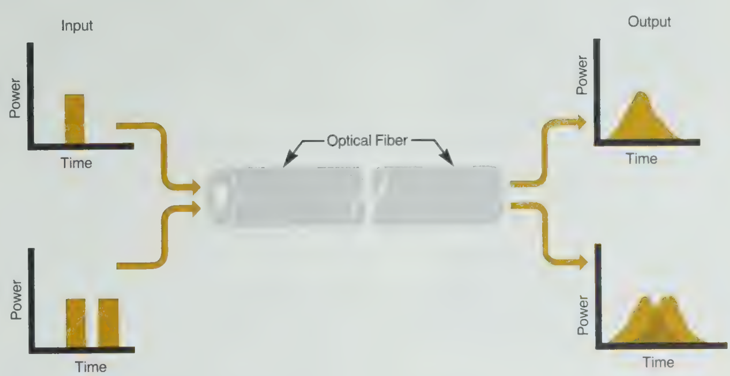


Figure 10—Pulse spreading in an optical fiber.

Dispersion makes the multimode step index fiber the least bandwidth efficient of the three types. It is therefore used for shorter runs and lower operating frequencies, e.g. 20 MHz-km.

Single mode fiber has small core sizes of 8 to 10μm diameter in order to allow only one lightwave ray to propagate down the fiber. Because modal dispersion is completely eliminated, this fiber has much greater bandwidths which can exceed several hundred gigahertz-kilometer (GHz-km).

However, fibers are susceptible to another type of dispersion problem caused by the fact that different wavelengths travel at different velocities through a medium.

This "spectral dispersion" is evident when white light decomposes into a rainbow of colors by a glass prism. Each wavelength travels at a different speed leading to unequal amounts of bending of the rays associated with each color.

If the fiber system's spectral source emitted a single frequency of light, this spectral dispersion, or material dispersion (or chromatic dispersion, as it is also often called) would be eliminated. However, an LED light source has a spectral range of about 20 times that of a laser, and thus has much greater spectral dispersion. Dispersion in glass fiber has a minimum around 1.3μm, allowing monomode fibers extremely large bandwidth capacities at this wavelength.

Single mode fiber is typically used with laser emitters, because of their greater spectral purity. Precision connectors and splicing are required.

Because of their low loss, and high capacity qualities, single mode fibers are the choice for constructing long, high-data rate links, such as cross-country telecommunications.

Between monomode and step index fibers, there are graded index fibers. Rays in a graded index fiber are gradually redirected back towards the core's axis during propagation to reduce the effects of modal dispersion. Graded index fibers have much greater bandwidth capacities than step index fibers. A 600 MHz-km graded index fiber can transmit a 20 MHz modulation signal as far as 30 km. The cost of this glass fiber is currently one of the lowest. Its low loss plus high bandwidth make it the fiber of choice for most local area network applications, for example.

Bandwidth Summary

To this point we've covered how pulse spreading or dispersion limits the maximum bandwidth that may be used with fibers. The different propagation pathways cause delays, or modal dispersion in multimode fibers.

Modal dispersion provides the principle bandwidth limitation for laser-based multimode fiber systems at 850 nanometers, and for both laser and LED systems at 1300 nanometers.

Spectral dispersion provides the principle bandwidth limitation for LED based systems at the first window of 850 nanometers of about 100 MHz-km, and for single mode laser-based systems typically more than 50 GHz-km at the 1300 nanometer region.

The basic loss mechanism, or attenuation, within fibers is caused by light scattering which varies by wavelength. The 1300 nanometer wavelength is important because not only is the attenuation low at this point, but spectral dispersion is generally a minimum at this wavelength.

Fibers have a constant loss over a wide range of modulation rates, but there is a rapid increase in effective loss when pulse dispersion becomes comparable to the pulse period at or near maximum bandwidth limits. Contrast this with baseband metallic systems where attenuation increases as the square root of the modulation rate. Provided dispersion is small, fiber systems do not require equalization and line amplifiers which are necessary with metallic systems.

Local Area Networks (LANs)

The explosive growth of personal computing in the business marketplace and the increasing sophistication of multiple-function local area networks are forcing system developers into an examination of not only what would be the optimum cable/system design.

The growing requirements for bandwidth in computer applications, and the need to adapt to other inter- and intra-building telecommunications needs such as telephone, security, alarm and video have all dramatically increased the demand for optical fiber.

Fiber optic LANs generally have a maximum link distance between transmitter/receiver pairs of 2km. They may be isolated to only one floor or one building, or be interconnected with other networks among several buildings.

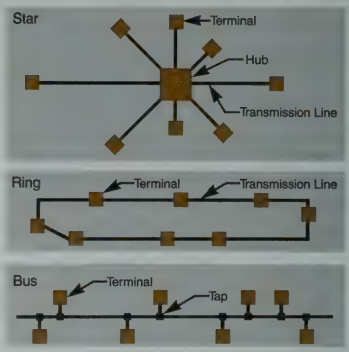


Figure 11—Several Basic LAN Topologies.

A system can be low-speed, low-capacity such as telephone, or high-speed high-capacity such as video. Although copper and fiber can both be used or intermixed in a LAN system, the high information capacity and upgradeability of fiber is increasingly making it the choice. Instead of rewiring to add future capacity, changing the electronic hardware at the system ends is all that's necessary to alter these systems. Many designers add extra fibers to a system for this purpose.

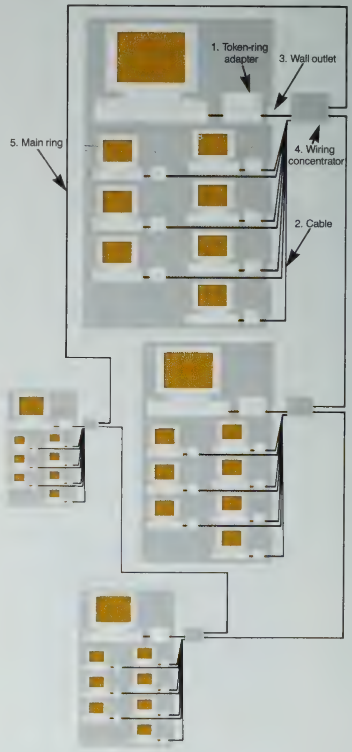


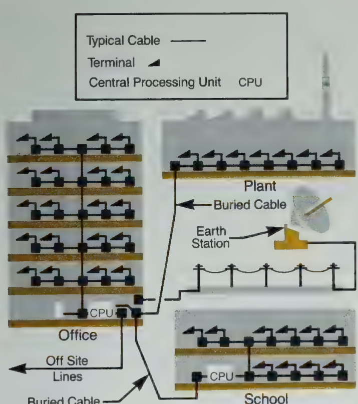
Figure 12— An example of IBM's ring LAN design capable of supporting 256 terminals.

Figure 11 shows several examples of the basic LAN topologies: star, ring, and bus.

Star LANs are arranged around a single hub that may act as a central controller for the network. Transmission sent from one node or terminal must first pass through the hub. This hub can simply be a passive star coupler or an active controller.

In a ring type network, all terminals are linked in a point-to-point series. If one part fails, the system is down unless bypass components are used. To avoid conflicting data demands such systems use a bit pattern, called a token. The token is circulated to each node allowing that node to capture the token and the right to transmit data. IBM has a ring architecture shown in Figure 12. Other systems and software are also on the market.

Networks based on a bus topology also use a token passing scheme, or an access scheme known as carrier-sense multiple access with collision detection (CSMA/CD), or collision avoidance (CSMA/CA). Like a ring, messages on the bus are broadcast to all terminals. Since all the terminals tap into a single main trunk channel like branches on a tree, messages do not have to be repeated.



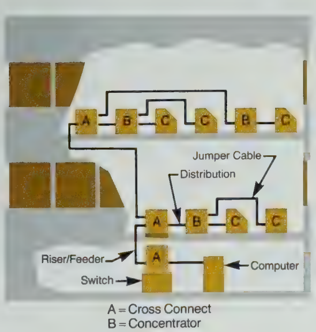


Figure 14— A typical single premise LAN.

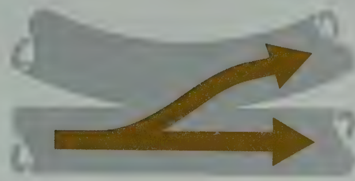


Figure 15— A T-coupler taps off or injects optical energy into another fiber. Such couplers are made by fusing two fibers together or some other optical configuration. Typical use in bus topology LAN's. Various ratio coupling levels are available, plus each coupler results in some small added loss of the optical power.

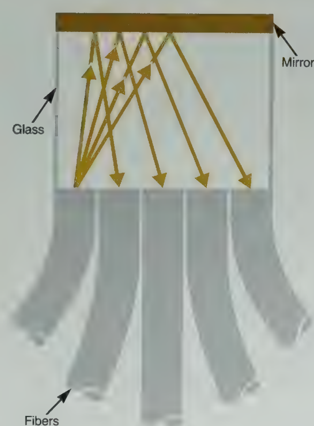


Figure 16—A star coupler allows terminal to communicate with all others by reflecting light from one port through a glass mixer into a mirror. Another form of star coupler consists of a tapered fused region formed with a number of optical fibers.

Most LANs use combinations of bus and star networks today because of speed, easy installations of retrofit, and the fact that each node can be passive so that if one fails the network keeps functioning.

Interconnecting Components

LAN networks can be easily configured because the fiber optic cable can be easily strung in a plenum on a single floor, up a raceway between floors, or among several buildings.

Figures 13 and 14 show typical examples of LAN layout for multi-premise and single locations. There are fiber optic component pieces corresponding to every piece of electronic hardware used with any other LAN type. These devices appear in a system wherever a user connects, or where several lines join together at a node. These devices can be active, such as the transmitters and receivers that have already been discussed, or passive such as taps, distributors, couplers, concentrators, switches, relays, multiplexers and cross connection cabinets. They are available from a variety of vendors as discrete components, in rack-mounted modules, of as fully integrated systems.

Optical taps or "T"s, and optical mixers or "star" couplers are shown in Figures 15 and 16. Both are examples of concentrators which actively or passively combine signals at nodes or user connection points in a LAN system.

Simple LAN systems use "T"s, stars, and other passive components between transmitter/receiver pairs. More complex systems require active components to combine, route and sometimes re-amplify the signal. Data transmissions trends as outlined in Figure 17 are moving toward more active nodes as the need for greater fiber optic system flexibility, data speed, and link length increases.

New standards such as the FDDI (Fiber Distributed Data Interface) ANSI X3T9.5 describe a LAN system which operates at 100 Mb/s. Still other options include the potential use of wavelength division multiplexing (WDM) to transmit various signals via different optical wavelengths.

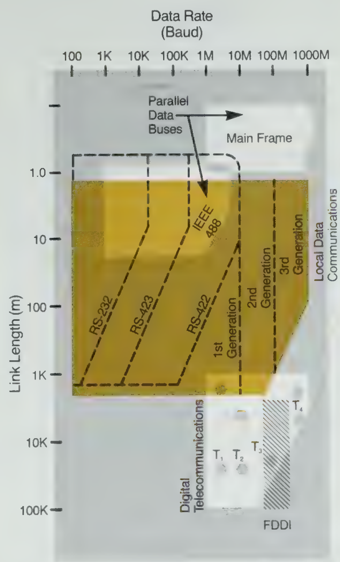


Figure 17—Data transmission standards and trends with respect to data rate vs. link length.

As previously discussed, optical power losses occur whenever a fiber is terminated of coupled. Therefore allowances for tapped bus or other LAN configurations require that connectors must be factored into the system's loss budget analysis. Since many connectors are used in typical LAN networks, each must have a known loss factor.

System Design Procedure

System Analysis

The system designers must proceed through the following five steps in order to develop a fiber optic communication system:

1. Specify the system's operational requirements.
2. Describe the physical and environmental requirements.
3. Compute the signal optical power budget.
4. Perform a signal bandwidth analysis.
5. Review the system design.

Important considerations in these steps of the design process are detailed in Figure 18. Worksheets for compiling all the data necessary to complete the design are included in the back of this section.

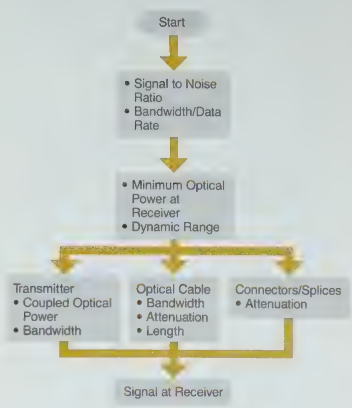


Figure 18—Considerations in developing a fiber optic system.

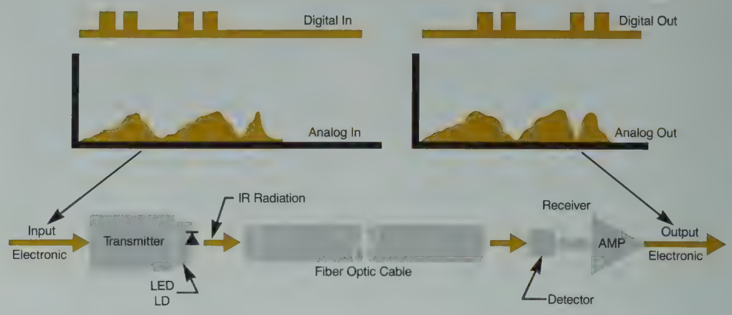


Figure 19—Fiber optic system for analog or digital transmission.

System Operational Requirements (Step 1)

The system design process begins with a determination of the signal-to-noise ratio which depends on the bandwidth or data rate for an application. This implies a choice of signal types, either analog or digital, since even a simple point-to-point link will employ appropriate hardware. The goal is to establish what optical power level will be required at the optical detector inside the receiver unit.

As shown in Figure 19, fiber can handle either analog or digital transmission and it offers the additional option of future upgrading by simply changing the electronics hardware at the transmitter and receiver ends. For this reason most fiber system designers specify more fiber bandwidth capacity than is minimally required.

Analog Signals

Analog signals such as video and audio can directly modulate optical output by causing the optical emitter to brighten and dim. This is called intensity modulation and is a simple and straightforward method of encoding lightwave signals.

Improvements in both signal-to-noise and linearity can be obtained by the use of frequency modulation (FM) techniques.

Here the information source is used to frequency modulate a subcarrier, then this signal is used to intensity modulate an LED or a laser. Because of material and intermodal dispersion factors, FM links normally require fibers with bandwidths of 200 MHz-km and higher. Short unrepeatered links are occasionally analog modulated. However most lightwave applications today use digital transmission with simple on-off modulation.

Digital Signals

In fiber optics, a digital pulse can be formed by turning the source "on" for a brief instant. The time of optical radiation emission is the pulse. A binary "1" state can be used to represent optical power turned "on", while a binary "0" state is used to represent "off". These two states represent binary signals. Digital signals consist of a series of bits that result in the emitter being "on" or "off" as shown in Figure 20.

The time it takes for a pulse to reach full emplitude is the rise time. Faster rise and fall times allow more pulses per second, consequently more bits of information can be transmitted.

In digital systems one parameter for system performance is bit error rate (BER). The majority of digital systems achieve a BER of 1 X 10^{-9} (1 error in 10^9 bits).

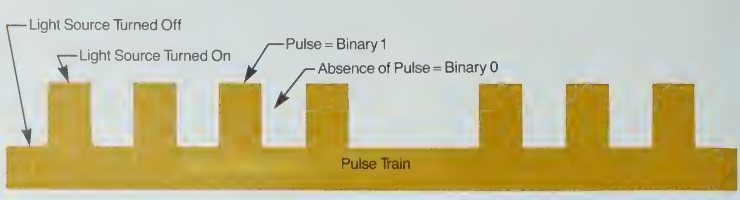
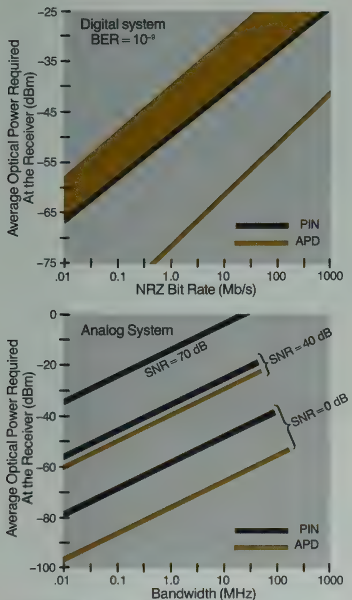


Figure 20—Each pulse represents a bit in digital transmission and the rise and fall times of a series becomes the bit rate.



NOTE: Shaded area represents common available sensitivity range.

Figure 21—Average otpical power required by digital or analog systems.

There is a length dependence with digital systems because the farther a pulse has to travel down a fiber the more distortion occurs. The resulting optical power level required at the detector is a function of the data rate or bandwidth. These levels for digital and analog signals are indicated for silicon detectors at 850 nm in Figure 21.

Once the application (TV, telephone, or computer), the type of signals (analog, digital), and the data rate have been determined, the next step is to describe the physical layout and environmental requirements.

System Layout (Step 2)

To determine the components necessary to complete a fiber optic system requires detailing run lengths and determining system operating environments.

A simple point-to-point system as shown in Figure 22, or a more elaborate local area network involving telephone, data, video, control and alarm functions as shown in Figure 23, are both commonplace installations for fiber optic cable. Current fiber optic technology employs a separate fiber to transmit the signals in one direction.

Therefore most point-to-point systems will require at least two fibers for duplex communications. Higher fiber count cables are also readily available.

The system designer should develop a layout schematic similar to the one shown in Figure 24 and use the resulting information on the worksheets at the back of this section.

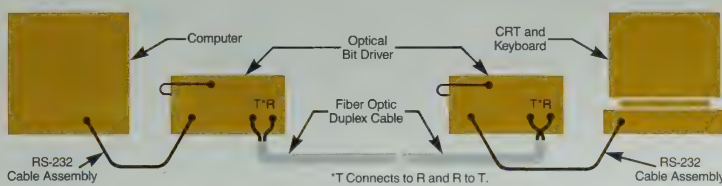


Figure 22—View of cable assembly hook-ups in a simple fiber optic link.

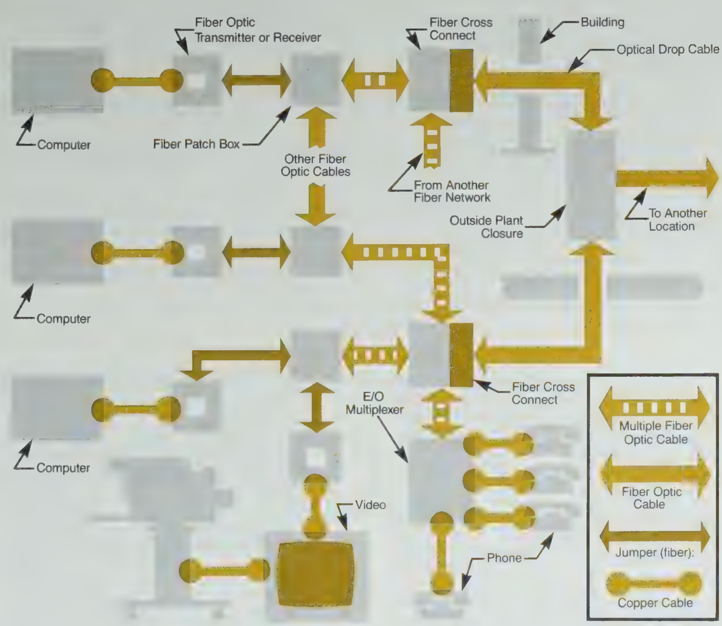


Figure 23—A wiring diagram for a fiber system incorporating telephone, computer and video links.

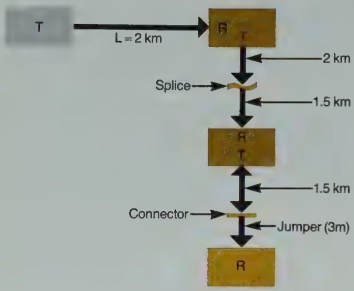


Figure 24—A fiber optic layout should detail distances between each fiber segment.

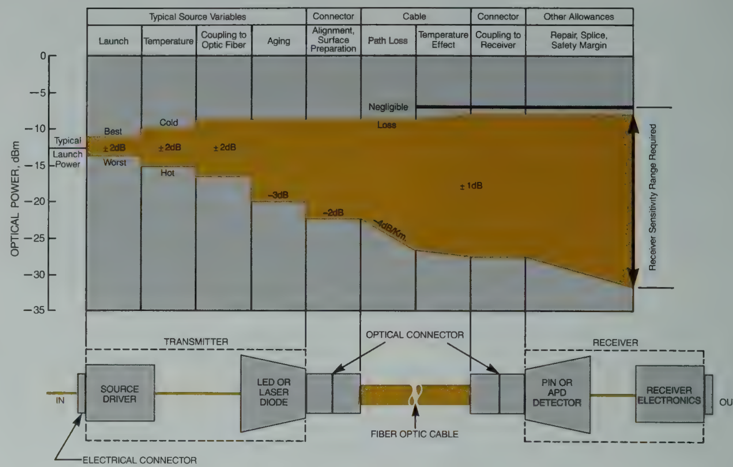


Figure 25—An Optical Link Power Analysis is done for each T/R pair.

Signal Optical Power Budget (Step 3)

With the system layout and components known, it's now possible for the designer to compute expected losses at each point in the system shown in Figure 25.

Every component including fiber has a range of optical loss due to variations in manufacture. An LED device, for example, will be specified with a minimum, average, and maximum optical output power. The range may be as much as 4dB (60%).

Detectors also have sensitivity ranges. It is up to the system designer to determine the optical power necessary at the detector surface from information supplied by the manufacturer.

Once the receiver and transmitter power levels have been established it is possible to consider the power transmitted by various cable lengths. This can be seen by plotting the power on a diagram such as in Figure 26.

In the example shown, a fiber with a 100 micron core has been analyzed for use with a 10 Mb/s transmitter at the 850 nanometer wavelength. Both the best and the worst case curves are shown with the average expected range in between.

The detector sensitivity upper and lower limits are also shown. This figure indicates that a transmission distance of about 1.4 km is maximum.

Starting power levels vary due to the emitter launch range. When taps and splices are included, their values can be considered as part of the launch loss, or displayed where they might occur in the system as in Figure 28.

Worksheets are included at the end of this section for determining your optical power budget. Use either peak or average optical power values for determining attenuation throughout the system. Be consistent in your choice throughout the system analysis.

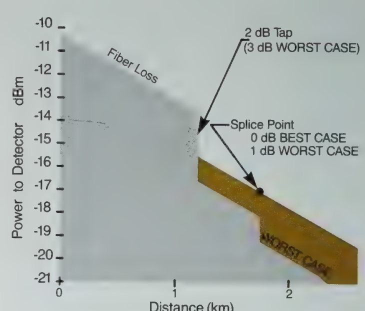


Figure 28—Typical optical power level in system with a tap and a splice.

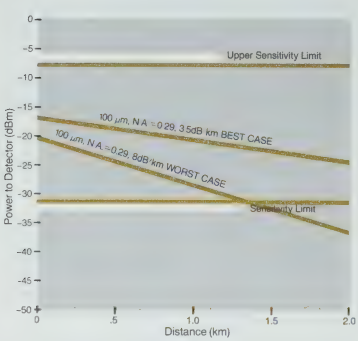


Figure 26—Use stated receiver and transmitter ranges to determine fiber distances (e.g. 10 Mb/s transmitter at 850 nm with 100 micron core fiber).

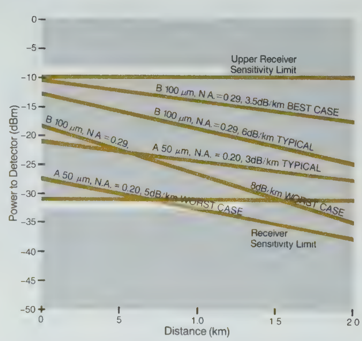
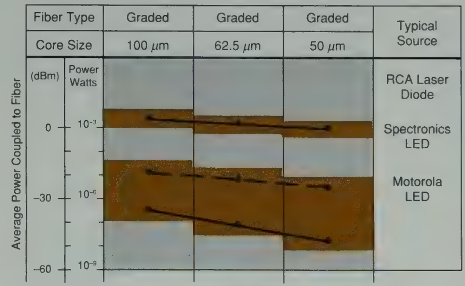


Figure 27—Fiber distances compared for two core sizes: 50 micron and 100 micron at 850 nm wavelength and 10 Mb/s.

Power coupled to various fiber types by a few typical source emitters is detailed in Figure 29. Coupled powers for each fiber type under consideration should be entered in the appropriate column on the worksheet. Allow approximately 4 to 6 dB to account for thermal variations in the optical fiber, repair of damaged cables, and source degradation over time.



Belden Cable Product No.	226XXX	225XXX	227XXX
Numerical Aperture	0.29	0.275	0.20
Maximum Attenuation at 850 nm	5 dB/km	3.75 dB/km	3 dB/km
Fiber Bandwidth	20 to 100 MHz-km	160 MHz-km	600 MHz-km

Figure 29—Optical source-to-fiber power coupling chart for various emitters.

Fiber selection

Basic fiber types are presented in Figure 30. The various fiber properties such as attenuation, numerical aperture (NA), core diameter have all been covered earlier in this section. NA and core diameter must be considered for launch conditions. All fibers can be compared over one kilometer lengths for fiber properties and relative optical power as in Table 7.

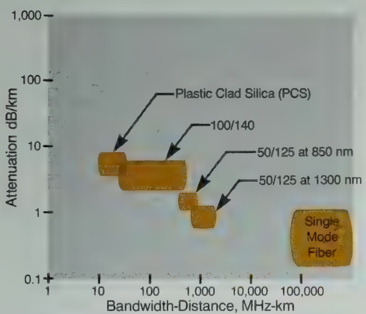


Figure 30—Operating properties for various fiber types.

Bandwidth					
Material Structure	Type	Core Dia. Micron (μm)	Numerical Aperture	Relative Collection Factor (dB)[1]	Relative Optical Power (dB) at 1 km[2]
Silica	Single Mode	10μm	0.11	-28.4	-23.9
Silica	Multimode	50	0.20	-9.25	-7.25
Silica	"	62.5	0.275	-4.54	-2.55
Silica	"	85	0.26	-2.36	-1.36
Silica	"	100	0.29	0.0	0.0
PCS	"	200	0.27	+5.4	+3.4

1. Relative amount of radiation coupled to fiber based on 1 km length NA value. Shorter lengths may have higher values.
2. Based on the difference in transmission over a 1 km length of cable using the 100 micron core fiber at 5 dB/km (850 nm) as the basis for normalization.
3. Primary use at 1300 or 1550 nm.

Table 7—Optical power comparison for various fiber types.

Certain fiber types have proven suitable for special applications.

Choices for most LAN or data systems, for example, currently centers on the all-silica fibers. Here various core/cladding constructions are available with tradeoffs in performance, cost, and standardization. Currently four sizes are most often considererd:

Core	Cladding	Bandwidth 850	Bandwidth 1300
50	125	400	400
62.5	125	160	500
85	125	200	200
100	140	100	200

All are mulitmode, graded-index fibers to assure adequate bandwidth and low enough loss to be ideal for typical LAN capacity and size requirements.

Video and CATV systems often employ 50/125 and single mode fibers because of their high bandwidth and low loss performance characteristics. Modern intercity telephone trunks also employ single mode fibers.

Fibers may be selected in a variety of bandwidths and attenuations, in either one or two window versions. Again, attenuation of optical fibers will vary depending on the source wavelength of the transmitter. A fiber cable loss table for Belden products is shown in Table 8 and can be used with the Step 3 Worksheet at the end of this section.

Material Structure	Core Dia. Micron (μm)	Numerical Aperture	Attn.* dB/km	Bandwidth MHz/km
Silica	50	0.20	0.275	600
Silica	62.5	0.29	3.75	160
Silica	85	0.26	4	200
Silica	100	0.29	5	100
PCS	200	0.27	7	10

*Values for 850 nm wavelength

Table 8—Belden Optical Fiber Cable Performance

Bandwidth Analysis (Step 4)

While attenuation is one major determinant in fiber optic system performance, bandwidth is the other. Here the goal is to assure that all components have sufficient bandwidth to transmit the required signal. Local area networks typically require 20 to 600 MHz-km fiber bandwidth. On the other hand, long-haul telephone systems employ large distances bewteen repeaters and require the 100,000 MHz-km fiber bandwidths associated with single mode fiber.

A fiber has a 3dB (half power) optical signal magnitude decrease at the bandwidth specified for that fiber. Conversion between electrical and optical bandwidth for the system or any component such as a fiber, receiver, or transmitter unit is performed by using:

BW optical = 1.41 BW electrical

In some cases a receiver or transmitter manufacturer will specifty risetimes. The electrical bandwidth (BW in MHz) for a component is related to its 10%—90% risetime (t in nanoseconds) by:

$BW = 350/t$

And the total system electrical bandwidth is obtained from individual component bandwidth by:

$$\frac{1}{BW^2} = \frac{1}{BW^2_R} + \frac{1}{BW^2_C} + \frac{1}{BW^2_T}$$

where BW_R, BW_C and BW_T are the electrical bandwidth of the receiver, cable and transmitter respectively.

For digital systems the system bandwidth will depend on the data rate (R in bits per second) and the coding format according to:

BW system = R/K

Where K equals 1.4 for a non-return-to-zero (NRZ) coding format and 1.0 for a return-to-zero (RZ) format.

The system bandwidth is limited by the lowest bandwidth component in the link. When high bandwidth fiber is used, for example, the system frequency response may be more influenced by the terminal equipment than the fiber.

A general guideline in selecting the terminal equipment is to choose a receiver with a bandwidth equal to or greater than the required system bandwidth. The transmitter and optical fiber should then have bandwidths about 1.5 to 2 times greater than the reciever.

Again, systems are usually more cost effective at higher data rates. And allowing for more fiber bandwidth than is minimally required, for example, allows system capacity to be upgraded later. Care should be taken in estimating the optical bandwidth in MHz-km of series connected cable runs with lengths greater than a kilometer.

The approximate relationship between the total cable bandwidth (BW_{CO}) and one kilometer section fiber bandwidth (BW_f) is:

$BW_f = BW_{CO} (L)^x$

L is the fiber length in kilometers. The x equals 1.0 for cable run lengths (L) of one kilometer or less. And x equals 0.75 for fiber in cable run lengths greater than 1 kilometer.

The Step 4 Worksheet provides a simple example and blank form to fill in the necessary values for a bandwidth analysis. Here the $\frac{1}{BW^2}$ terms are individually calculated and then combined in a series of steps to yield the total system bandwidth.

System Review (Step 5)

Now is the time for the system designer to review all of the pieces to determine that all work together to deliver the right signal to the right place at the right time. These combined parameters can be listed in the final Step 5 Worksheet.

For a more detailed analysis of cable construction parameters such as buffers, jackets and strength members, consult catalog pages 10–28, which describe fiber optic cables. The number of fibers for a cable depends on the number of channels or signal carrying capacity desired. Cables employing fibers with special high bandwidths are available as custom products.

The complete cable structure can be established using the following criteria:

- Cable Construction
  Hybrid ______ All Dielectric
  Metal Strength Members
- Jacket Materials
  PVC ______ Polyurethane ______
  Polyethylene ______ Other
- Environmental Protection
  Flame Retardancy ______
  or UL code ______
  Sunlight Resistance ______
  Water Resistance ______
  Water Blocking (gel fill) ______
  Rodent Protection (armor) ______
  Nuclear Radiation Resistance ______
  Other ______
- Chemical Resistance
  To Oil ______, Acid ______,
  Alkali ______, Solvents ______
- Fiber Features
  Number of Fibers
  Fiber Type ______, Core Size ______
  Wavelength ______
  Attenuation ______
  Bandwidth ______
  NA ______
  Double Window ______
- Number and type of electrical conductors ______

Specific materials and multi-fiber construction have resulted in numerous cable designs which incorporate a variety of fibers to meet specific applications. Hybrid designs having both optical fibers and metallic conductors are also part of the Belden® fiber optic cable line.

Hopefully this guide will permit the identification and description of a useful fiber optic system. Due to advancing technology and extensive tradeoffs, system design is constantly changing. This guide is based on currently available components. To keep abreast of changes, ask questions, or to request design assistance, contact Belden's local sales representative or the regional offices listed on the back cover of this catalog.

System Operational Requirements. (Step 1)

Application

TV________ Telephone________ Computer________ Other________

Type of Signals

Analog:
- System Bandwidth ________ MHz
- System Signal-to-Noise Ratio ________ dB

Digital:
Coding Scheme NRZ________ RZ________ Other________
Data Rate ________Bits per second
Bit Error Rate 10^{-8}________ 10^{-9}________ Other________
Logic Format ________TTL ________ECL ________Other

- (A) Minimum Required Receiver Optical Power (from manufacturer's data) ________ dBm Average________ Peak________
- (R) Receiver Dynamic Range (from manufacturer's data) ________ dBm
- (S) Maximum optical power allowed at receiver (A + R) ________ dBm Average________ Peak________
  Number of Channels ________

Terminal Equipment

Space available for:
Transmitter________" × ________" × ________"
Receiver ________" × ________" × ________"
Repeater ________" × ________" × ________"

Terminal Equipment Connections RS-232________ BNC________ Other________
Terminal Equipment Mounting PC Board________ Rack________ Other________

Power Supply Requirements:
Voltages AC________ DC________ Volts________
Current________mA
Frequency________Hz

System Layout. (Step 2)

System Location

Locations of Equipment Building________ Other________
Distance Between Stations ________Meters
Routing Plan for Cables ________

System Environment

For Terminals and Repeaters Indoor________ Outdoor________
For Cables (based on routing) Ducts________ Buried________ Aerial________ Other________
Temperature Range ________°C to________°C
High Voltage Present ________No ________Yes ________Volts
Water Presence ________No ________Yes

Installation Constraints

Installation Equipment ________
Cable Pull Lengths ________Meters

Signal Optical Power Budget. (Step 3) Example

	Required Bandwidth (Data Rate)	(NRZ, 1.4 Mb/s)
	Required Bit Error Rate	10^{-9}
(L)	Required Length of Run	2 km
(A)	Minimum Optical Power Required for PIN Type Receiver	–39 dBm Average
(R)	Receiver Dynamic Range	20 dB
(S)	Maximum Optical Power Allowed at Receiver (A + R)	–19 dBm
	Transmitter Type (Wavelength):	LED 850 nm

	Source-to-Fiber Coupling: Fiber (Core dia.)	200μm	100μm	50μm
(B)	Coupled Power (From Figure 26)	–5 dBm	–11 dBm	–20 dBm
(C)	Power Difference (B-A)	34 dB	28 dB	19 dB
(D)	Degradation Allowance	6 dB	6 dB	6 dB
(E)	Power Margin (C-D)	28 dB	22 dB	13 dB
(F)	2 Connectors (Average Loss: 0.5 to 3dB/Connector)	6 dB	1 dB	1 dB
(G)	0 Splice (Average Loss: 0.25 dB/splice)	0 dB	0 dB	0 dB
(H)	Maximum Cable Attenuation Allowed (E-F-G)	22 dB	21 dB	12 dB
(I)	Cable Attenuation at 850 nm (From chart in Figure 26)	8 dB/km	6 dB/km	5 dB/km
(J)	Total Cable Loss (I x L)	16 dB	12 dB	10 dB
	Maximum Cable Length Allowed (H/I)	2.75 km	3.5 km	2.4 km
(K)	Excess Power Margin	6 dB	9 dB	2 dB

Signal Optical Power Budget. (Step 3) Worksheet

	Required Bandwidth/Data Rate	______		
	Required Bit Error Rate	______		
(L)	Required Length of Run	______ km		
(A)	Minimum Optical Power Required for ______ Type Receiver	______ dBm	Average______	Peak______
(R)	Receiver Dynamic Range	______ dB		
(S)	Maximum Optical Power Allowed at Receiver (A + R)	______ dBm		
	Transmitter Type (Wavelength):	LED______ nm	Laser Diode______ nm	Other Source______ nm

	Source-to-Fiber Coupling: Fiber (Core dia.)	μm	μm	μm
(B)	Coupled Power (From Figure 26)	dBm	dBm	dBm
(C)	Power Difference (B-A)	dB	dB	dB
(D)	Degradation Allowance	dB	dB	dB
(E)	Power Margin (C-D)	dB	dB	dB
(F)	Connectors (Average Loss: ______dB/Connector)	dB	dB	dB
(G)	Splices (Average Loss: ______dB/splice)	dB	dB	dB
(H)	Maximum Cable Attenuation Allowed (E-F-G)	dB	dB	dB
(I)	Cable Attenuation (at above source wavelength)	dB/km	dB/km	dB/km
(J)	Total Cable Loss (I x L)	dB	dB	dB
	Maximum Cable Length Allowed (H/I)	km	km	km
(K)	Excess Power Margin	dB	dB	dB

Signal Bandwidth Analysis. (Step 4) Example

Receiver Bandwidth PIN Type:	BW_R = 10	MHz
(A)	$1/BW_R^2$ = 10^{-2}	MHz^{-2}
Transmitter Bandwidth LED Type:	BW_T = 20	MHz
(B)	$1/BW_T^2$ = 2.5×10^{-3}	MHz^{-2}
Fiber Optic Cable Bandwidth		
(C)	Fiber Length L = 2 km	

	Fiber (Core dia., Type)	200 μm	100 μm	50 μm
(D)	Bandwidth BW_f	25 MHz-km	20 MHz-km	200 MHz-km
(E)	Cable Optical Bandwidth BW_{CO}	12.5 MHz	11.9 MHz	118.9 MHz
(F)	Cable Electrical Bandwidth BW_C (E/1.41)	8.9 MHz	8.4 MHz	84.3 MHz
(G)	$1/BW_C^2$	1.3×10^{-2} MHz^{-2}	1.4×10^{-2} MHz^{-2}	1.4×10^{-5} MHz^{-2}
	System Bandwidth			
(H)	Sum of Squares (A + B + G)	2.5×10^{-2} MHz^{-2}	2.6×10^{-2} MHz^{-2}	1.3×10^{-2} MHz^{-2}
(I)	System Bandwidth $1/\sqrt{H}$	6.3 MHz	6.2 MHz	8.8 MHz
(J)	Required System Bandwidth	1.0 MHz	1.0 MHz	1.0 MHz
(K)	Bandwidth Margin (I–J)	5.3 MHz	5.2 MHz	7.8 MHz

Signal Bandwidth Analysis. (Step 4) Worksheet

Receiver Bandwidth ________ Type:	BW_R = ________	MHz
(A)	$1/BW_R^2$ = ________	MHz^{-2}
Transmitter Bandwidth ______ Type:	BW_T = ________	MHz
(B)	$1/BW_T^2$ = ________	MHz^{-2}
Fiber Optic Cable Bandwidth		
(C)	Fiber Length L = ______	

	Fiber (Core dia., Type)				
(D)	Bandwidth BW_f	________MHz-km	________MHz-km	________MHz-km	________MHz-km
(E)	Cable Optical Bandwidth BW_{CO}	________MHz	________MHz	________MHz	________MHz
(F)	Cable Electrical Bandwidth BW_C (E/1.41)	________MHz	________MHz	________MHz	________MHz
(G)	$1/BW_C^2$	________MHz^{-2}	________MHz^{-2}	________MHz^{-2}	________MHz^{-2}
	System Bandwidth				
(H)	Sum of Squares (A + B + G)	________MHz^{-2}	________MHz^{-2}	________MHz^{-2}	________MHz^{-2}
(I)	System Bandwidth $1/\sqrt{H}$	________MHz	________MHz	________MHz	________MHz
(J)	Required System Bandwidth	________MHz	________MHz	________MHz	________MHz
(K)	Bandwidth Margin (I–J)	________MHz	________MHz	________MHz	________MHz

System Review. (Step 5)

System Considerations	Example	Requirements For Operation
Data Rate (Bandwidth)	1.4 MB/S (1.0 MHz)	
Signal-to-Noise Ratio (Analog)		
Bit Error Rate (Digital)	10^{-9}	
Coding Scheme (Digital)	NRZ	
Receiver		
Type	PIN	
Bandwidth	10 MHz	
Sensitivity		
Minimum Optical Power	–39 dBm Average	
Bit Error Rate	10^{-9}	
Dynamic Range	20 dB	
Transmitter		
Bandwidth	20 MHz	
Coupled Optical Power	–5 dBm	
Wavelength/Type	850 nm/LED	
Optical Fiber		
Fiber Type	200μm core	
Bandwidth	25 MHz-km	
Attenuation (at Transmitter Source Wavelength)	8 dB/km	
Fiber Length	2 km	
Number of Splices	0	
Total Splice Attenuation	0 dB	
Number of Connectors	2	
Total Connector Attenuation	6 dB	
Degradation Allowance	6 dB	
Excess Power Margin	6 dB	
Bandwidth Margin	5.3 MHz	

System Costs.

The cost of each component should be totaled to determine the system cost.

(Qty.)				
______	Connectors at	$______/connector	=	$______
______	Transmitters at	$______/transmitter	=	$______
______	Receivers at	$______/receiver	=	$______
______	km of Cable at	$______/kilometer	=	$______
______	Repeaters at	$______/repeater	=	$______
		Installation Costs	=	$______
		Maintenance Costs	=	$______
		Other Costs	=	$______
		Total System Cost	=	$______

Installation Procedures

The following section contains information on the placement of fiber optic cables in various indoor and outdoor environments. In general, fiber optic cable can be installed with many of the same techniques used with conventional copper cables. Basic guidelines that can be applied to any type of cable installation are as follows:

- Conduct a thorough site survey prior to cable placement.
- Develop a cable pulling plan.
- Follow proper procedures.
- Do not exceed cable minimum bend radius.
- Do not exceed cable maximum recommended load.
- Document the installation.

Conduct a Site Survey

The purpose of a site survey is to recognize circumstances or locations in need of special attention. For example, physical hazards such as high temperatures or operating machinery should be noted and the cable route planned accordingly. If the fiber optic cable has metallic components, it should be kept clear of power cables. Additionally, building code regulations, like the National Electric Code (NEC)** must be considered. If there are questions regarding local building codes or regulation, they should be addressed to the authority having jurisdiction, such as the fire marshall or city building inspector.

Develop a Cable Pulling Plan

A cable pulling plan should communicate the considerations noted during the site survey to the installation team. This includes the logistics of cable let-off/pulling equipment, the location of intermediate access points, splice locations and the specific responsibilities of each member of the installation team.

Follow Proper Procedures

Because fibers are sensitive to moisture, the cable end should be covered with an end cap, heavy tape or equivalent at all times. The let-off reel must never be left unattended during a pull because excess or difficult pulls, center-pull or backfeeding techniques may be employed.

Do Not Exceed Cable Minimum Bend Radius

Every Belden cable has an installation minimum bend radius value. During cable placement it is important that the cable not be bent to a smaller radius. After the cable has been installed, and the pulling tension removed, the cable may be bent to a radius no smaller than the long term application bend radius specification.

The minimum bend radii values still apply if the cable is bent more than 90 degrees. It is permissible for fiber optic cable to be wrapped or coiled as long as the minimum bend radius constraints are not violated.

Do Not Exceed Cable Maximum Recommended Load

While fiber optic cables are typically stronger than copper cables, it is still important that the cable maximum pulling tension not be exceeded during any phase of cable installation. In general, most cables designed for outdoor use have a strength rating of at least 600 lbs. Belden fiber optic cables also have a maximum recommended load value for long term application. After cable placement is complete the residual tension on the cable should be less than this value. For vertical installations, it is recommended that the cable be clamped at frequent intervals to prevent the cable weight from exceeding the maximum recommended long term load. The clamping intervals should be sufficient to prevent cable movement as well as to provide weight support.

Leave Extra Cable

A common practice is to leave extra cable at the beginning and at the end of the cable run. Also, extra cable should be placed at strategic points such as junction boxes, splice cases and cable vaults. Extra cable is useful should cable repair or mid-span entry be required.

Document the Installation

Good record keeping is essential. This will help to ensure that the cable plant is installed correctly and that future trouble shooting and upgrading will be simplified. All Belden fiber optic cables have a unique lot number shown on the shipping spool. It is important that this number be recorded. Cable pre- and post- installation test data should be recorded in an orderly and logical fashion.

Pulled Installations

In order to effectively pull cable without damaging the fiber, it is necessary to identify the strength material and fiber location within the cable. Then, use the method of attachment that pulls most directly on the strength material—without stressing the fiber.

As a general rule, it is best to install cable prior to connector attachment. After connectors have been attached, it becomes more difficult to protect the fiber from inadvertent stress. If a pull is to be made entirely in one direction, connectors may be pre-installed on one end, leaving the other end for pulling.

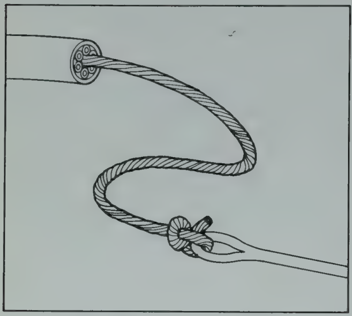
If the cable *must* be installed with connectors attached, every practical means must be taken to protect the connectorized end from damage or stress. Cushioned enclosures should be used to protect connectors during pulling.

The leading end of the cable should be sealed to prevent intrusion of water or other foreign material while pulling.

Bi-directional pulls are possible by laying the cable into large "figure-8"-shaped loops on the ground, from where it can feed into duct work.

For ease of cable installation, the area of the cable divided by the area of the duct or conduit should be less than 53% per a single cable. Permissible area to be occupied for 2 cables is 31%, for 3 or more cables it is 40%.

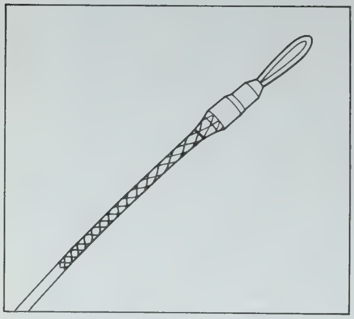
** Trademark of National Fire Protection Association, Quincy, MA.



Direct Attachment: Strength member is tied directly to the pulling fixture. The cable end must be sealed to prevent intrusion of moisture while pulling.

Direct Attachment

With direct attachment, cable strength material is tied directly to the pulling fixture. Conventional cable tools may be used. Loose fiberglass threads are not suitable for direct attachment because they may break if knotted. Fiberglass epoxy rods are too rigid to tie, but may be secured to the pulling fixture by using tight clamping plates or screws.



Indirect Attachment: Pulling forces are distributed over the outer cable structure.

Indirect Attachment

With indirect attachment, pulling forces are distributed over the outer portion of the cable structure. If cable strength materials are located directly beneath the jacket, this method will produce the least amount of stress on the fiber.

A popular type of pulling fixture for indirect attachment is the "Chinese Basket" or "Kellems Grip".■ The Kellems Grip is usually reliable for cables of 1/4" diameter or more. Large pulling forces are possible with a Kellems Grip if the grip's diameter and length are properly matched to cable characteristics.

A Kellem Grip should spread pulling forces over a 1-1/2 to 3-foot length of cable. For small cables, pre-stretching and taping the Kellems Grip to the cable helps to assure even pulling.

Cable Lubricants

Many types of lubricants are available for lowering friction forces. These include greases, waxes, clay slurries and water-based gels. Fiber optic jacket materials are compatible with most of these. For new conduit, lubrication of the conduit before pulling is suggested—particularly if there are several bends.

Air Plenums, Trays, Raceways

Installation procedures for open placement of fiber optic cables are the same as for electrical cables. Care should be taken to avoid sudden, excessive force so as not to violate tensile load and radius limits. Sharp bending and scraping at entrances and covers should be avoided.

For indoor applications, NEC♦♦-rated OFNR (riser) and OFNP (plenum) should be used to satisfy building code regulations. It is always recommended to check local authorities prior to cable installation.

Direct Burial

Belden outdoor cables may be buried directly in the ground. Environmental hazards include freezing water, crushing forces from rocky soil, ground disruption from construction, and rodents. Burying the cable 36 to 48 inches deep may help prevent most of these hazards.

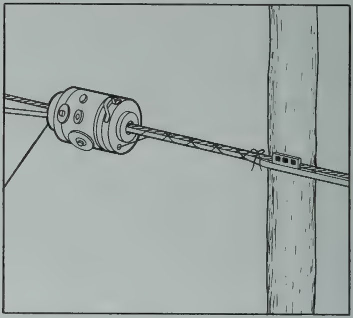
Direct plow-in installation requires a cable capable of withstanding uneven pulling forces. Loose tube cables are best suited for these types of installations.

Double jacketing, gel filling, metal sheathing and armoring are used as water barriers.

Use of double jacketed armored cables can sometimes be avoided by burying polyethylene pipe to form a simple conduit. The pipe makes a smooth passageway and may be curved to allow easy access at manholes and other pull points. Cables may be subsequently replaced without digging.

Aerial Lashing

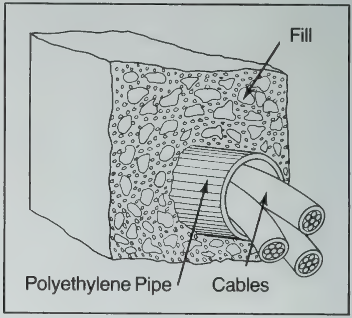
Most round, loose tube cables are compatible with helical lashing, clamping or tied mounting. Cables for long outdoor installation are usually temperature stabilized. The stabilizing member may be steel or fiberglass/epoxy rod—depending on potential electrical or lightning hazards.



Aerial lashing of a fiber optic cable.

Cable Storage

It is frequently required to store cables prior to installation. Temperature ranges for cable storage are listed in the corresponding catalog pages. It is recommended that cable ends be sealed to prevent intrusion of moisture.



Polyethylene pipe can be used as a simple conduit. This allows use of less expensive cables in direct burial applications.

■ Harvey Hubbell Trademark
♦♦ Tradename of National Fire Protection Association, Quincy, MA.

Cable Preparation

The following is a general description of cable preparation and termination procedures.

Jacket Removal

The procedure for stripping fiber optic cables is very similar to electronic cables. However, care should be taken not to cut into the layer of Kevlar• directly beneath the jacket. This would either reduce the pull strength of the cable, or weaken the connection. For this reason, if a blade must be used, a cut which does not completely penetrate the jacket can be made. This will weaken it sufficiently and allow the jacket to be peeled.

Most Belden cables utilize a ripcord capable of tearing the outer sheath.

Cutting and Trimming Kevlar

Kevlar can be easily cut with sharp scissors if the threads are confined in movement so that cutting pressure can be applied. Ceramic scissors may also be used.

Steel and Fiberglass Epoxy Rod Members

Temperature stabilized cables of both loose and tight buffer constructions often have steel or fiberglass epoxy rods. Use of heavy-duty cutters is recommended for these hard materials.

Buffer Tube Trimming

Buffer tubes are made of plastic materials with various characteristics of hardness and flexibility. Belden® buffer tubes are both flexible and strong, but may be trimmed easily. The simplest way is to score one side of the buffer tube firmly with a razor blade, then bend the tube sharply away from the score mark. The broken-off piece is then pulled straight off, leaving the fiber intact.

A stripping tool which barely cuts through the tube is also satisfactory. If it is intended to cut through both the buffer tube and the fiber, use diagonal cutters and cut through cleanly.

Breakout Element Trimming

Breakout subunit element jackets are most easily removed by a stripping tool which cuts circumferencially. The jacket may then be pulled straight off, exposing the Kevlar.

Fiber Preparation

Fiber Stripping

NOTE: ALWAYS WEAR SAFETY GLASSES OR GOGGLES WHEN WORKING DIRECTLY WITH FIBERS.

Optical fibers must be stripped of buffer coatings to allow a close fit within precision connectors.

Mechanical Stripping

Buffer coatings are usually removed mechanically with sharp blades or calibrated stripping tools. In any type of mechanical stripping, the key is to avoid nicking the fiber.

NOTE: DISPOSE OF BROKEN PIECES OF FIBER BY PLACING THEM ON A PIECE OF TAPE. GLASS FIBERS ARE DIFFICULT TO SEE AND MAY NOT BE FELT UNTIL THROUGH THE SKIN. EYES SHOULD NOT BE RUBBED.

Connector Attachment

Belden® fiber optic cables are available on a custom-order basis with connectors preattached. These cable assemblies are ready for direct connection to their mating components and feature 100% optical attenuation testing.

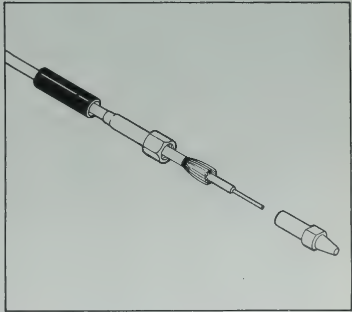
Fiber Optic Connectors

Fiber optic connectors position fiber ends to receive or transmit light. The surfaces must be smooth and perpendicular to the fiber axis for greatest efficiency in accepting light rays. Rough, slanted or dirty end surfaces block and scatter light.

Because glue-and-polish connectors are widely used, the following discussion of cable termination procedures will be based on using this type of connector.

Termination Procedure

The first step in the termination procedure is to slide the heat-shrink tubing and connector retaining assembly over the cable jacket. Then, cable materials may be stripped to the appropriate lengths—as specified by the connector manufacturer. The cable is now ready for termination.



Cable prepared for termination.

Most glue and polish systems use two-part epoxy to fasten fibers into ferrules. Setting time can range from 5 minutes to 24 hours. Five-minute epoxies are useful for fast installation in non-critical environments. Longer setting epoxies are better suited for applications where fiber strain and temperature extremes are major concerns.

Heat setting epoxies are useful for situations where many connectors are to be attached. Since these epoxies set only when heat is applied, the need for mixing separate batches is often eliminated.

Before ferrules are filled with epoxy, a trial insertion of fiber should be made. Coating residue on the fiber, or a clogged ferrule may prevent insertion. Detecting such problems at this stage will help save time and ferrules.

Apart from polishing, the most critical part of connector installation is cementing the fiber securely in the ferrule. If the fiber is not evenly glued on all sides, it may crack below the end surface. See connector manufacturer instructions for recommendation of quantity of adhesive to be used.

To provide strain relief, the connector retaining assembly is crimped over the Kevlar strength material. This type of strain relief can typically withstand pulling tension of up to 50 lbs.

The assembly can now be set aside to cure.

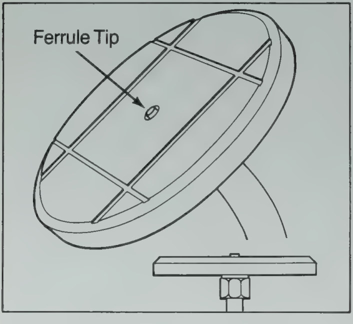
• DuPont Trademark.

Connector Finishing

After the epoxy has been thoroughly cured, the long piece of fiber may be removed by a simple cleave (see section on cleaving) and break from the point where it protrudes from the ferrule.

Grinding

The grinding/polishing fixture allows the ferrule tip to protrude beyond a flat reference surface, which provides a physical limit for grinding and polishing perpendicular to the fiber axis.



The grinding/polishing fixture establishes the minimum final polished length of the ferrule tip.

Wet papers are used for grinding and polishing. The coarse grinding process may use from 50 to 600 grit size. Also, dry papers are often used.

The initial grinding step removes excess fiber and epoxy from the ferrule tip. It also establishes a rough dimension for tip length.

A smooth level surface is needed for this operation. *Very light* pressure should be used for initial grinding until a flat surface develops on the end face. Best results can be obtained by gently moving the fixture in a small figure-8 pattern (about 1" loops) against the grinding surface. Grinding motion should be smooth and light. DO NOT PRESS HEAVILY.

After completing this step, the fixture and connector must be thoroughly rinsed in clean water to remove all coarse grit.

Polishing

This stage removes most of the coarse scratches from the grinding process. Wet papers, typically of 3-13 micron grit, are used. Use the same figure-8 motion with slightly more pressure—still not heavy. Upon completion, the ferrule end should appear satin. A fine scratch pattern will be seen under magnification. Again, the fixture and connector must be rinsed thoroughly.

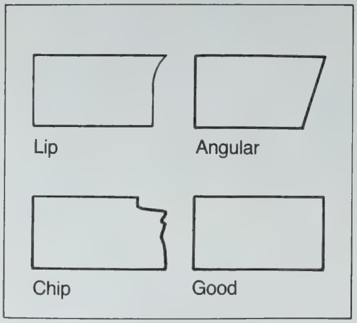
The final step utilizes papers as fine as 0.3 micron. This is also a wet procedure. Apply the same firm, but not heavy pressure as in the prior polishing step.

Final polishing requires approximately 45 seconds to complete. A high-gloss surface should develop on plastic and stainless steel ferrules.

Ceramic-Tipped Connectors

Ceramic-tipped connectors afford more precision in fiber placement than similar metal types, but require modified polishing methods. Almost no ceramic is ground away because of the material's hardness, and it is possible to grind the fiber below the ceramic with a concave end surface, thereby reducing optical efficiency.

Manufacturers' methods minimize epoxy bead formation around the protruding fiber and use polishing devices which produce convex end surface on the fiber end. Follow manufacturer's directions.



Fiber end surfaces are inspected after cleaving.

Illustration of fiber ends after polishing. The fiber end on the left would require additional polishing.

Inspection

After polishing is completed, the fiber end should be inspected with a 30x to 200x microscope. This will show if the fiber is well centered and free from chips. The fiber end should be viewed under oblique light which will most clearly show scratches. If a major scratch appears across the center of the core area, additional polishing may remove it. Scratches outside the core area are generally not considered critical.

When polishing is successfully completed, remove the fixture and position the strain relief in place behind the ferrule cap. When not in use, always protect connectors with dust caps.

Splicing Optical Fibers

Preparation of Fibers

Preparation of fibers for splicing is very similar to the process described under connectorization. After jacket materials, strength members and buffer tubes have been cut to the appropriate lengths, the fiber buffer coatings must be removed.

Cleaving

After the buffer coatings have been removed, fibers must be cleaved in preparation for splicing. Cleaving is a method of breaking a fiber in such a way as to create a smooth, square end on the fiber.

Principles of Cleaving

Glass is typically strong until a flaw occurs and creates a region of high stress under pressure. The first step in the cleaving process is to create a slight flaw or "scribe" in the outer surface of the fiber.

Optical fibers can be scribed with a sharp blade of hard material such as a diamond, ruby, sapphire or tungsten carbide. The scribe is made by *lightly* touching the cleaned fiber, at a right angle, on the desired cleave point with a scribing tool. Only the lightest pressure is required to produce a scribe if the blade is sharp. NOTE: DO NOT USE A SAWING MOTION. A crude or slanted scribe will produce shattered or scalloped end surfaces.

After the scribe is made, a *straight* pull will produce the cleanest break. If bending accompanies pulling, a square break is less likely, especially with large fibers. Dispose of broken fiber pieces by placing them on a piece of tape. ALWAYS WEAR SAFETY GLASSES WHEN WORKING WITH OPTICAL FIBERS.

The level of quality required for a given cleave depends on the application. For fusion splicing, mechanical splicing and some connectors systems, cleaves must be nearly perfect. Some connector and splicing systems use cleaving to produce the *final* end surface on the fiber (no subsequent grinding or polishing). However, for quick continuity checks with a flashlight, less than perfect cleaves may be acceptable.

A 30x to 50x hand microscope is useful for quick checks of cleave quality.

Cleaving tools are available in inexpensive hand models or more sophisticated mechanized tools.

Splicing Optical Fibers

Splicing Methods

There are two basic types of splices: Fusion and Mechanical.

Fusion Splicing

Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together. A prefusion arc is applied to the fiber while the ends are still separated to vaporize volatile materials which could cause bubbles.

Final precise alignment is done by moving fiber ends together until there is slight pressure between end surfaces.

An ideal fusion cycle is short and uses a ramped or gradually increasing arc current. A short, ramped cycle is considered least likely to produce excessive thermal stress in fibers. Cold temperatures require increased time and arc current.

Experienced operators consistently produce fusion splices with losses less than 0.2 dB per splice and averaging 0.3 dB on multimode fibers. Sophisticated fusion splicing systems for single-mode fibers produce typical splice losses of 0.05 to 0.1 dB.

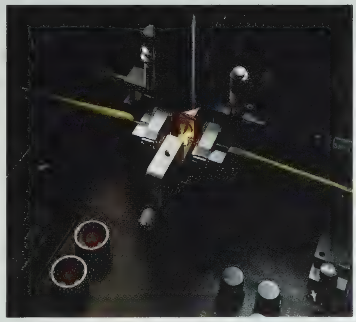
Mechanical Splicing

Mechanical splicing systems position fiber ends closely in retaining and aligning assemblies. Focusing and collimating lenses may be used to control and concentrate light that would otherwise escape. Index matching gels, fluids and adhesives are used to form a continuous optical path between fibers and reduce reflection losses.

In-Line Connector/Connector Splicing

Connector-to-connector splicing may be used in situations where there is an abundance of optical power. Connectorized cable assemblies are joined through an alignment bushing which fits snugly over the tip of each connector.

Insertion losses for connector-to-connector splices can be as high as 1.0 to 1.5 dB. If these losses are considered excessive, an alternative method should be used.



Fusion splicing system. Fiber ends are aligned and positioned under a microscope.

Testing

Methods

The Flashlight Test

A simple continuity test for short-to-medium length fiber optic links is to shine a flashlight into a cleaved or connectorized link and observe if light comes out of the other end. On short lengths, it may be necessary to cleave only the end where the flashlight injects light into the fiber.

This simple check can be made on cable lengths of up to a mile and more. If cable ends are outdoors, sunlight may be used. NOTE: On longer lengths, the light observed at the opposite end may appear red in color. This is normal and is caused by the filtering of light within the fiber.

CAUTION: NEVER LOOK DIRECTLY INTO A FIBER CONNECTED TO LIGHT LAUNCHING EQUIPMENT. THIS CAN CAUSE PERMANENT EYE DAMAGE.

Optical Power Measurements

When an optical cable has been installed, all splices made and connectors attached, it must be determined if the system is capable of delivering the required power. The simplest test requires a light source of the same type, wavelength and approximate power as that of the equipment to be used. The system equipment itself is often a satisfactory source.

The first step is to obtain an approximate measure of system launch power. A short test cable with the same fiber and connector style as the installed cable can be used for this procedure. One end of the short cable is connected to the light-launching equipment. The other end is connected to an optical power meter.

After the initial reading is taken on the short length of test cable, a second similar reading is taken with the installed cable in place. The difference between the two readings indicates the additional power losses due to fiber length and differences in optical qualities of connectors. Because approximate fiber losses are known, losses greater than 1.0 to 1.5 dB *above* fiber losses might indicate an inferior connection—requiring either repolishing or replacement.

Equipment

Optical Power Meters

Power meters often read directly in power units, such as dBm and dBμ. By using connector adapters and light sources of the same wavelength as the installed equipment, an accurate measure of link losses with connectors and splices may be obtained.

The Optical Time Domain Reflectometer (OTDR)

OTDRs are typically used to measure distance and attenuation over the entire fiber link. They are also used to identify specific points along the link where losses occur, such as splices.

An OTDR is an optical radar which measures time of travel and the return strength of a short pulse of light launched into an optical fiber. Small reflections occur throughout the fiber, becoming weaker as power levels drop with distance. At major breaks, large reflections occur and appear as strong peaks on an oscilloscope.

Testing of short and medium distance fiber optic systems seldom requires an OTDR. In smaller systems, optical power meter tests are faster and more useful.

Many instrument rental companies are now offering OTDR's as well as other fiber optic splicing and test equipment.

Magnifying Glasses and Microscopes

Because the naked eye cannot detect scratches or defects in optical fibers, use of magnification equipment is required. For most routine inspections, and ordinary battery-powered illuminated microscope of 30x to 100x can produce satisfactory results.

Some microscopes are available with special adapters specifically designed for use with fiber optic connectors.

Optical Power and Decibel Scales

Because light is energy, measurements of the rate of delivery or power are important. Compared with common light bulbs of 40 or more watts, LEDs and laser diodes are very low in power.

Power levels commonly experienced in fiber optics are milliwatts (1/1000) of a watt), microwatts (1 millionth of a watt), and nanowatts (1 billionth of a watt). Relative power levels of typical LEDs and laser diodes are shown on the chart below.

The Decibel Scale

When making calculations, it can be difficult to handle factors of 1,000,000 and 1,000,000,000. The decibel scale allows us to compress these figures and use simple addition and subtraction of decibel figures instead of multiplication and division of lengthy numbers.

Many optical test instruments use the dBm and the dBµ scales below. The "m" indicates the zero dB reference value is 1 mw (0.001 watt = 1 milliwatt). The "μ" indicates the zero reference level is one microwatt.

In this scale, a change of 10 dB changes the value considered by a factor of 10. Plus 10 dB (+ 10 dB) increases the value 10 times. Minus 10 dB (–10 dB) decreases to 1/10 the value.

Table of Decibel Values related to Zero dBm

				Relative Levels (Exact levels vary with sources and fibers used)
	+ 30 dBm	=	1.0 w	
	+ 20 dBm	=	.1 w	
	+ 10 dBm	=	.01 w	Laser Diodes
+ 30 dBμ =	0 dBm	=	.001 w = 1 milliwatt	
+ 20 dBμ =	- 10 dBm	=	.0001 w = 100 microwatts	
+ 10 dBμ =	- 20 dBm	=	.00001 w = 10 microwatts	LEDs
+ 0 dBμ =	- 30 dBm	=	.00001 w = 1 microwatt	
- 10 dBμ =	- 40 dBm	=	.000001 w = 100 nanowatts	Received Power
- 20 dBμ =	- 50 dBm	=	.00000001 w = 10 nanowatts	

Two other conventional decibel values to use are:

3 dB = Factor of 2: + 3 dB = 2x, –3 dB = (1/2)x

6 dB = Factor of 4: + 6 dB = 4x, –6 dB = (1/4)x

A *loss* or reduction of power, is designated by a minus (-dB) decibel number.

Metric Conversion Chart

(Celsius X 1.8) + 32	=	Fahrenheit
Kilometers X .6214	=	Miles
Kilometers X 3281	=	Feet
Meters X 3.281	=	Feet
Centimeters X 0.3937	=	Inches
Millimeters X .03937	=	Inches
Micrometers X .0000394	=	Inches

1 Micron = 1 Micrometer =
1 Millionth of a Meter

Attenuation	The decrease in magnitude of power of a signal in transmission between points. A term used for expressing the total losses on an optical fiber consisting of the ratio of light output to light input. Attentuation is usually measured in decibels per kilometer (dB/km) at a specific wavelength. The lower the number, the better the fiber. Typical multimode wavelengths are 850 and 1300 nanometers (nm); single-mode, at 1300 and 1500 nm. NOTE: When specifying attenuation, it is important to note if it is nominal or average, room temperature, value or maximum over operating range.
Bandwidth	Measure of the information-carrying capacity of an optical fiber, normalized to a unit of MHz-km. NOTE: This term is used to specify capacity of multimode fibers only. For single-mode fibers, use dispersion.
Bend Loss	A form of increased attenuation caused by (a) having an optical fiber curved around a restrictive radius of curvature or (b) microbends caused by minute distortions in the fiber imposed by externally induced perturbations.
Bend Radius	Radius of curvature that a fiber optic or metallic cable can bend without any adverse effects.
Breakout	Multifiber cable constructed in the tight buffered design. Designed for ease of connectorization and rugged applications for intra- or interbuilding requirements.
Buffer	A protective coating over the fiber.
Cladding	A low refractive index material that surrounds the core and provides optical insulation and protection of the core.
Central Member	The center component of a cable. It serves as an anti-buckling element to resist temperature-induced stresses. Sometimes serves as a strength element. The central member is composed of steel, fiberglass, or glass-reinforced plastic.
Coating	A material put on a fiber during the drawing process to protect it from the environment.
Connector	A mechanical device used to align and join two fibers together to provide a means for attaching and decoupling it to a transmitter, receiver or another fiber. Commonly used connectors include the FC, FC-PC, Biconic, ST Connector-Compatible, D4, SMA 905 or 906.
Core	The light conducting central portion of an optical fiber with a refractive index higher than that of the cladding.
Decibel (dB)	Unit for measuring the relative strength of a signal.
Dielectric	Non-metallic and, therefore, non-conductive.
Dispersion	The cause of bandwidth limitations in an optical fiber. Dispersion causes a broadening of input pulses along the length of the fiber. Two major types are (a) mode dispersion caused by differential optical path lengths in a multimode fiber, and (b) material dispersion caused by a differential delay of various wavelengths of light in a wave guide material.
EIA	Electronic Industries Association. A standards association that publishes test procedures. See FOTP.
Fiber	A single, separate optical transmission element characterized by a core and a cladding.
Fiber Optics	Light transmission through optical fibers for communication and signalling.
FOTP	Fiber Optic Test Procedures
Fusion Splice	A permanent joint accomplished by the application of localized heat sufficient to fuse or melt the ends of optical fiber.
Gigahertz (GHz)	A unit of frequency equal to one billion hertz.
Graded-Index Fiber	A type of fiber where the refractive index of the core is lower toward the outside of the fiber. It bends the rays inward and also allows them to travel faster in the lower index of refraction region. This type of fiber provides high bandwidth capabilities.

IEEE	Institute of Electrical and Electronics Engineering
Index of Refraction	The ratio of light velocity in a vacuum to its velocity in a given transmitting medium.
Injection Laser Diode (Source)	Sometimes called the semiconductor diode. A laser in which the lasing occurs at the junction of n-type and p-type semiconductor materials.
Jumper	Fiber optic cable that has connectors installed on both ends.
Light Emitting Diode (LED-Source)	A semiconductor device that emits incoherent light formed by the P-N junction. Light intensity is roughly proportional to electrical current flow.
Local Area Network (LAN)	A geographically limited communications network intended for the local transport of data, video and voice.
Loose Tube	Type of cable design whereby coated fibers are encased in buffer tubes offering excellent fiber protection and segregation. Mainly utilized for outdoor cables.
Mechanical Splicing	Joining two fibers together by mechanical means to enable a continuous signal. Elastomeric splicing is one example of mechanical splicing.
Megahertz (MHz)	Unit of frequency equal to one million hertz
Micron (μm)	Millionth of a meter = 10^{-6} meter.
Mode	A term used to describe a light path through a fiber, as in multimode or single mode. A single electromagnetic field pattern within an optical fiber.
Modulation	The coding of information onto the carrier frequency. Modulation means include (among others) amplitude, frequency, or phase, plus many forms of on-off digital coding.
Multifiber Cable	An optical cable that contains two or more fiber, each of which provides a separate information channel.
Multimode Fiber	An optical waveguide in which light travels in multiple modes. Typical core/cladding sizes (measured in microns) are 50/125, 62.5/125, and 100/140.
Multiplex	To put two or more signals into a single channel.
Nanometer (nm)	One billionth of a meter = 10^{-9} meter.
NEC	National Electrical Code. Defines building flammatory requirements for indoor cables.
Numerical Aperture (NA)	A measure of the angular acceptance for a fiber. It is approximately the sine of the half-angle of the acceptance cone. $NA = \sqrt{n_1^2 - n_2^2}$ Where n_1 and n_2 are, respectively, the refractive index of the core and the cladding.
Optical Waveguide Fiber	A transparent filament of high refractive index core and low refractive index cladding that transmits light.
PE	Abbreviation used to denote polyethylene. A type of plastic material used to make cable jacketing.
Photodetector (Receiver)	Transforms light into electricity. The silicon photo diode is most commonly used for relatively fast speeds and good sensitivity in the 0.75μm to 0.95μm wavelength region. Avalanche photodiodes (APD) combine the detection of optical signals with internal amplification of photo-current. Internal gain is realized through avalanche multiplication of carriers in the junction region. The advantage in using an APD is its higher signal-to-noise ratio, especially at high bit rates.

Pigtail	Fiber optic cable that has connectors installed on one end.
Pin-diode	A photodetector used to convert optical signals to electrical signals in a receiver.
Plenum	Air duct inside building through which cable can be pulled or housed.
PVC	Polyvinylchloride. Material used in the manufacture of a type of jacketing material.
Receiver	An electronic package that converts the optical signal to an electrical signal.
Repeater	A receiver and transmitter combination used to regenerate an attenuated signal.
Riser	Application for indoor cables that pass between floors. It is normally a vertical shaft or space.
Scattering	A property of glass which causes light to deflect from the fiber and contributes to losses.
Single-Mode Fiber	An optical waveguide (or fiber) in which the signal travels in one "mode." The fiber has a small core diameter.
Source	The means (usually LED or laser) used to convert an electrical information-carrying signal into a corresponding optical signal for transmission by an optical wave guide.
Spectral Bandwidth	The difference between wavelengths at which the radiant intensity of illumination is half its peak intensity.
Speed of Light (c)	2.998×10^8 meters per second.
Star Coupler	Optical component which allows emulation of a bus topology in fiber optic systems.
Step-Index Fiber	A fiber in which the core is of a uniform refractive index, and there is a sharp decrease in the index of refraction at the cladding.
Stop Bits	Serial asynchronous data transmission relies upon the stop bit(s) to signify to the receiver that no more data bits follow. Stop bits are longer in duration than normal data bits and this extended length allows them to be distinguished from normal data bits. Serial communications may be configured to allow for either 1, 1.5, or 2 stop bits (however, the most common number is 1).
Tap	A device in the feeder cable that connects a device to a network.
TCP/IP	Transmission control protocol/internet protocol. A specification that conforms to the latest Department of Defense Arpanel standard. The protocol corresponds to layers three and four of the ISO/OSI model.
TDM	Time division multiplexing. A method of using channel capacity efficiently, in which each node is allotted a small time internal, in turns, during which it may transmit a message or portion of a message. Nodes are given unique time slots during which they have exclusive command of the channel. The messages of many channels are interleaved for transmission and then de-multiplexed into their proper order at the receiving end.
Throughput	The total useful information processed or communicated during a specified time period. Expressed in bits per second or packets per second.
Tight Buffer	Type of cable construction whereby each glass fiber is tightly buffered by a protective thermoplastic coating to a diameter of 900 microns. High tensile strength rating is achieved, providing durability, ease of handling and ease of connectorization.
Token Bus	A network with a bus or tree topology using token passing access control.
Token Passing	A method whereby each device on a local area network receives and passes the right to use the channel. Tokens are special bit patterns or packets, usually several bits in length, which circulate from node to node when there is no message traffic. Possession of the token gives exclusive access to the network for message transmission.

Token Ring	The token access procedure used on a network with a sequential or ring topology.
Topology	Network topology can be centralized or distributed. Centralized networks, or star-like networks, have all nodes connected to a single node. Alternative topology is distributed; that is, in the limit, each node is connected to every other node. Typical topology names include bus, ring, star, and free.
Traffic	The measurement of data movement, volume, and velocity over a communications link.
Transceiver	A device required in baseband networks that takes the digital signal from a computer or terminal and imposes it on the baseband medium.
Transmission Line	An arrangement of two or more conductors or a wave guide used to transfer signal energy from one location to another.
Transmission Medium	The physical mechanism that allows for signals to be passed from one data communications device to another.
Transmitter	The electronic package that converts an electrical signal to an optical signal.
Transparency	A data communications mode that enables equipment to send and receive bit patterns of any form, without regard to interpretation as control characters. The user is unaware that this is taking place.
Turn-Key	A contractual arrangement in which one party designs and installs a system and "turns over the keys" to another party who will operate the system.
U.L.	Underwriters' Laboratories, Inc.
Velocity of Propagation	The transmission speed of electrical energy in a length of cable compared to speed of light in free space. Usually expressed as a percentage.
Wavelength	The distance between two crests of an electromagnetic waveform.
Wave Form	A graphical representation of a varying quantity. Usually, time is represented on the horizontal axis, and the current or voltage value is represented on the vertical axis.

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221706		20	225524		22	227312	OFNR	15	229888	CMP-OF	18	551708		24
221708		20	225536		22	227318	OFNR	15	229889	CMP-OF	18	551710		24
221710		20	225548		22	227324	OFNR	15	550259	OFNR	13	551712		24
221712		20	225560		22	227411		21	550260	OFNR	13	551716		24
221716		20	225572		22	227412		21	550261	OFNR	13	551718		24
221718		20	225713		22	227413		21	550262	OFNR	13	551724		24
221724		20	225714		22	227414		21	550263	OFNR	13	551736		24
221736		20	225715		22	227415		21	550264	OFNR	13	551748		24
221748		20	225716		22	227416		21	550265	OFNR	13	551760		24
221760		20	225717		22	227417		21	550266	OFNR	13	551772		24
221772		20	225718		22	227418		21	550267	OFNR	13			
221802	OFNP	13	225724		22	227424		21	550268	OFNR	13			
221811	OFNP	11	225736		22	227436		21	550269	OFNR	13			

National Electrical Code (NEC++) Catalog Reference Information

The National Electrical Code is a set of guidelines describing procedures which minimize the hazards of electrical shock, fires, and explosions caused by electrical installation. The text of the NEC is contained in nine chapters, each chapter broken into individual articles.

NEC types are acronyms consisting of a prefix describing cable type (e.g. coax, CATV, fiber optic) and a suffix indicating the type of flame test it has passed and where it can be installed. Articles describing wire and cable products—including required cable markings—are listed in the chart to the right.

Impact of the NEC

Almost everyone involved with wire and cable is affected by the National Electrical Code. In particular, the following groups must incorporate NEC guidelines into their work: OEM engineers, wire product engineers, distributors, installers, and architects.

Although the NEC is virtually universal in the premise wiring applications it covers, each individual municipality, city, county, or state can decide whether or not it will adopt the 1990 version of the NEC as law. Local inspectors and fire marshalls enforce their own codes. They have the right to accept or refuse an installation, in accordance with local laws. One of the organizations local inspectors rely on to test wire and cable is Underwriter's Laboratories (U.L.).

New NEC Catalog Reference Information

NEC Article/Type		Description	Installation Type: Plenum	Riser	Commercial	Residential
725	CL2	Class 2 cables	CL2P	CL2R	CL2	CL2X*
	CL3	Class 3 cables	CL3P	CL3R	CL3	CL3X*
	PLTC	A stand-alone class. This is a power-limited tray cable—a CL3-type cable which can be used outdoors. Is sunlight and moisture resistant and must pass the vertical tray flame test.	(none)	(none)	PLTC	(none)
760	FPL	Power-limited, fire protective signalling circuit cable	FPLP	FPLR	FPL	(none)
770	OFC	Fiber cable also containing metallic conductors	OFCP	OFCR	OFC	(none)
	OFN	Fiber cable only containing optical fibers	OFNP	OFNR	OFN	(none)
800	CM	Communications	CMP**	CMR**	CM	CMX*
	MP	Multi-Purpose Cables	MPP	MPR	MP	(none)
820	CATV	Community antenna television and radio distribution system	CATVP	CATVR	CATV	CATVX**

* Cable diameter must be less than 0.250″.
** Cable diameter must be less than 0.375″.

C.S.A. Flame Tests

FT 1 Vertical Flame Test per C.S.A. C22.2 No. 0.3-M1985 Para 4.11.1

Belden products passing the FT 1 Vertical Flame Test are designated FT 1 in the column where the trade number appears. This flame test ensures that "finished cable shall not propogate a flame or continue to burn for more than one (1) minute after five (5), fifteen (15) second applications of the test flame. There is an interval of fifteen (15) seconds between flame applications."

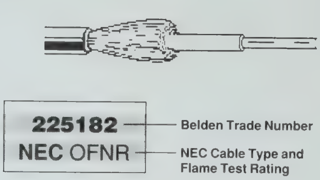
FT 4 Vertical Flame Test — Cables in Cable Trays per C.S.A. C22.2 No. 0.3-M1985 Para 4.11.4

Belden products passing the FT 4 Vertical Flame Test are designated FT 4 in the column where the trade number appears. This test is for cables in cable trays and is similar to but more severe than the U.L. 1581 Vertical Tray Flame Test. FT 4 has its burner mounted at 20° from the horizontal with its burner ports facing up, while the U.L. 1581 has its burner at 0° from the horizontal. Flame spread allowable is only 1.5 m (4.92 ft.).

FT 6 Horizontal Flame and Smoke Test per C.S.A. C22.2 No. 0.3-M1985

Belden products passing the FT 6 Horizontal Flame and Smoke Test are designated FT 6 in the column where the trade number appears. This test is for cables which must pass a Horizontal Flame and Smoke Test in accordance with ANSI/NFPA Standard 262-1985 (U.L.-910). The maximum flame spread shall be 1.50 meters (4.92 ft.). The smoke density shall be 0.5 at peak optical density and 0.15 at maximum average optical density.

Examples of Standards Referenced in the Belden Fiber Optic Catalog



++ Tradename of the National Fire Protection Association, Quincy, MA.

*PCC = Premise Communications Cable
or
CXC = Coaxial Cable
or
FAS = Fire Alarm and Signal Cable

** The supplementary letters "-OF" shall be added immediately after the type letters for each cable that contains one or more optical-fiber members.

Other Belden® Products and Literature

BELDEN
COOPER INDUSTRIES

The Belden product line offers a solution to virtually any cabling need. It includes hook-up and lead wire, multi-conductor, multi-paired, coaxial, flat, fiber optic, plenum, high-temperature, special application cables, power cords, and molded cable assemblies. The following literature is available from Belden to help you in your design, specification and implementation process. To request literature, check the literature desired, fold, seal, and mail to Belden. Or call: **1-800-BELDEN-4**

Catalogs and Sales Aids

- ❑ Master Catalog
- ❑ LAN Cable Catalog
- ❑ Broadcast Cable Catalog
- ❑ CATV Cable Catalog
- ❑ Appliance Cable Catalog
- ❑ Hook-Up Wire and Lead Wire Catalog

Application Reports

- ❑ Fiber Optics Facilitates Learning
- ❑ Belden Shielded Cable Decreases Electromagnetic Interference
- ❑ Unique Fiber Optic Link Replaces Rigid Coax
- ❑ Dataway Links Real-time Management
- ❑ Standard Cable Cuts Kawasaki Test Cost
- ❑ UnReel® Cartons Speed Cable Pulling by 60%
- ❑ Two Indianapolis Cable Franchises Link-Up with Fiber Optics
- ❑ Fiber Backbone Prepares Medical Center for the 21st Century
- ❑ Variety of Cable Links Belden Headquarters & New Engineering Center
- ❑ How Southwestern Bell Telephone Built a LAN for the Future (Intervention Breeds Invention)
- ❑ Fiber Optics Network Links Harvard Campus
- ❑ Multicon Inspects Product Quality with Custom Belden Cable
- ❑ Belden Coax Helps Put American Industry on the Map
- ❑ Belden Provides the Critical Link for the R. Adams Cowly, M.D., Shock Trauma Center

Technical Bulletins

- ❑ Ensuring Thinnet System Performance (T/8-51)
- ❑ Underground Burial of Belden Electronic Cables (T/8-6)
- ❑ Beldfoil® Multiple Pair Individually Shielded Cables and (ColorCoding) (T-8/7)
- ❑ Plugs/Connector Strain Relief (T/41)
- ❑ Strain and Flex Relief (T/41-2)
- ❑ Common Axis vs Separate Axis Cables (T/8-21)
- ❑ Termination of 9310 and 9311 (T/8-34)
- ❑ Calculating Sag and Span (T/8-36)
- ❑ Cable Pulling Techniques (T/8-37)
- ❑ Computer Cable Selection (T/8-39)
- ❑ Selection & Installation of CATV Cable (T/8-45)
- ❑ Measuring Vari-Twist® Series Flat Cable (T/8-44)
- ❑ Portable Cordage Tech Data (T/8-47)
- ❑ Attachment of AMP® Fiber Optic Connector (T/FO-5)
- ❑ 9913 and 9914 Low Loss 50 ohm Coaxial Cable (T/8–48)
- ❑ Cable Assemblies—How Cable Twist (T/97-3)

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